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SUMMARY OF TESTING FOR TRACE CONTAMINANTS IN THE BIOSATELLITE III SPACECRAFT ATMOSPHERE

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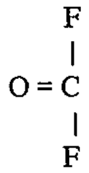
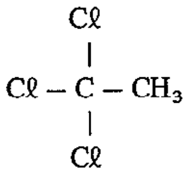
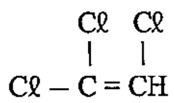
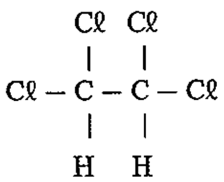
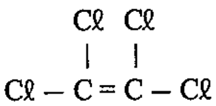
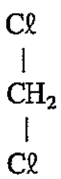
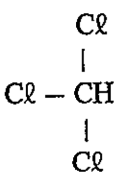
SYMBOLS

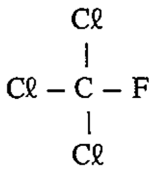
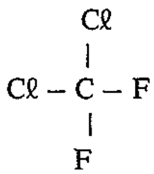
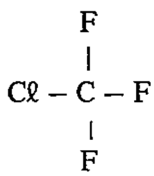
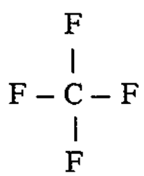
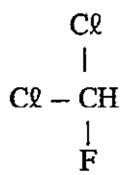
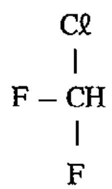
mg/m^3	milligrams of compound per cubic meter of atmosphere (concentration)
PPM or ppm	parts per million by volume for gases, by weight for solids (concentration) mg/m^3 = (mol wt of compound/24 375) PPM at nominal cabin conditions temperature = 23 9° C, pressure = 760 mm Hg
PVC	polyvinyl chloride
$\mu g/g$	micrograms of compound per gram of charcoal (concentration)

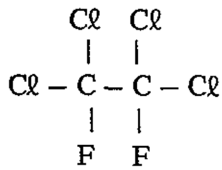
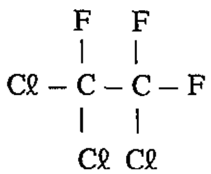
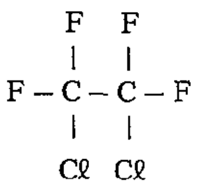
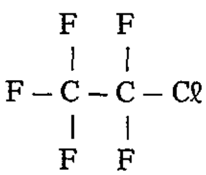
NOMENCLATURE FOR SOME HALOGENATED COMPOUNDS

(* denotes name used herein)

Structure	Compound name(s)
$\begin{array}{l} C\ell \\ \vert \\ C = CH_2 \\ \vert \\ C\ell \end{array}$	1,1 dichloroethylene vinylidene chloride*
$\begin{array}{lcl} C\ell & & C\ell \\ \vert & & \vert \\ H_2C & = & CH_2 \end{array}$	cis-dichloroethylene (1,2)* cis-dichloroethane acetylene dichloride
$\begin{array}{lcl} C\ell & & \\ \vert & & \\ H_2C & = & CH_2 \\ & & \vert \\ & & C\ell \end{array}$	trans-dichloroethylene (1,2)* trans-dichloroethane acetylene dichloride
$C\ell - C \equiv C - C\ell$	dichloroacetylene* 1,2 dichloroethyne
$\begin{array}{l} C\ell \\ \vert \\ HC = CH_2 \end{array}$	vinyl chloride chloroethylene*
$C\ell - C \equiv CH$	monochloroacetylene* chloroethyne
$\begin{array}{r} C\ell \\ \vert \\ O = C \\ \vert \\ C\ell \end{array}$	carbonyl chloride phosgene*

Structure	Compound name(s)
	carbonyl fluoride fluorophosgene*
	methyl chloroform 1,1,1 trichoroethane*
	1,1,2 trichloroethylene trichloroethylene* triclene ethinyl trichloride
	tetrachloroethane 1,1,2,2 tetrachloroethane*
	tetrachloroethylene* 1,1,2,2 tetrachloroethylene perchloroethylene perclene
	methylene chloride methyl dichloride dichloromethane*
	chloroform* trichloromethane

Structure	Compound name(s)
	Freon 11* fluorotrichloromethane Halon 11
	Freon 12* dichlorodifluoromethane Halon 12
	Freon 13* chlorotrifluoromethane Halon 13
	Freon 14* tetrafluoromethane Halon 14
	Freon 21* fluorodichloromethane Halon 21
	Freon 22* chlorodifluoromethane Halon 22

Structure	Compound name(s)
	Freon 112* 1,2 difluorotetrachloroethane
	Freon 113* 1,1,2 trichloro, 1,2,2 trifluoroethane trifluortrichloroethane
	Freon 114* dichlorotetrafluoroethane 1,2 chlorotetrafluoroethane
	Freon 115* chloropentafluoroethane

SUMMARY OF TESTING FOR TRACE CONTAMINANTS IN THE BIOSATELLITE III SPACECRAFT ATMOSPHERE

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SUMMARY

BIOSATELLITE III was the first U S spacecraft to maintain a normal earth atmosphere for its biological-specimen payload Preflight ground tests showed that the spacecraft atmosphere contained undesirable trace contaminants Strict control was imposed over the introduction of nonmetallic materials and the use of solvents in and around the flight spacecraft cabin and its components External ambient atmospheres were also controlled A series of tests verified that the resulting atmosphere was safe for long-term occupancy by the experimental animal The atmosphere of the recovered BIOSATELLITE III contained higher levels of a few contaminants than were detected in the preflight tests, and the ammonia and aldehyde levels were especially high, but none of the contaminants are thought to have reached toxic concentrations

INTRODUCTION

BIOSATELLITE III was the first U S spacecraft to provide a normal earth atmosphere for the occupant, a 6 4 kg monkey The atmosphere was required to be free of contaminants that might affect the monkey's health and thereby affect the experiment

During the first extended-duration ground test of a prototype spacecraft the physical condition of the experimental animal declined after 8 days and he was removed He died 7 days after removal A replacement animal remained in the spacecraft for 16 days without apparent ill effect although changes in heart rate and breathing similar to those noted for the first animal occurred during the first 8 days of his occupancy Toxic contaminants in the spacecraft cabin atmosphere were suspected as the cause of the decline of the first animal, although no conclusive pathological evidence was found During the continuation of the test with the second animal, atmosphere samples showed the presence of small amounts of chlorinated hydrocarbons These included trichloroethylene, which has been shown to react with hydroxides to produce dichloroacetylene (dichloroethyne), a very toxic gas (ref 1) The BIOSATELLITE utilized lithium hydroxide (LiOH) to remove carbon dioxide from the atmosphere, but an activated charcoal bed upstream of the LiOH eliminated most trace contaminants before they could reach the LiOH Subsequent to the test, the charcoal was analyzed and found to contain dichloroacetylene as well as other undesirable contaminants It was therefore apparent that the spacecraft atmosphere required more investigation, whatever the actual cause of the first primate's illness

A review of the information available on contaminants found in other closed atmospheres and in the initial BIOSATELLITE tests suggested a list of substances that should be anticipated and

which should be kept well below toxic concentrations With the assistance of the National Academy of Sciences' Advisory Center on Toxicology, safe limits were defined by NASA-OSSA Bioscience Office for 36 individual contaminants These limits were based largely on published information applicable to 90-day habitation of a spacecraft by humans (ref 2) and are considered to be the best that are presently available Limits on total hydrocarbons and total chlorides were imposed for BIOSATELLITE in order to assure that the presence of a number of individually small amounts of contaminants would not in summation represent a toxic condition Some compounds such as trichloroethylene, although not dangerous by themselves, are suspected to be precursors of very toxic substances therefore, the limit for these compounds was arrived at by considering the toxicity of the product compound, assuming that less than 10 percent of the reactant would be converted to the product The limits used for BIOSATELLITE are given in table 1

The spacecraft contractor implemented stringent controls on the introduction of nonmetallic materials into the flight spacecraft, and the use of volatiles in and around the cabin and its components was severely restricted A program was established to test the flight spacecraft cabin, the gases fed into it, components that would be installed or changed close to the launch date, and monkeys that were prepared in the same manner as the flight monkey These tests were devised with the assistance of the BIOSATELLITE Experimenters, NASA Headquarters (OSSA), NASA Kennedy Space Center Malfunction Investigation Branch, NASA Langley Research Center, USAF School of Aviation Medicine, General Electric Company Reentry and Environmental Systems Division, NASA Manned Spacecraft Center, Naval Research Laboratory, and Aerojet-General Corporation Azusa Facilities The ambient atmospheres to which the open capsule or the monkey would be exposed (e g , the manufacturing facility and the gantry) were also sampled and analyzed Commitment to launch the spacecraft was based upon establishing a prediction of acceptably low atmosphere contaminant concentrations by these controls and tests

The orbital flight of BIOSATELLITE III was terminated after 8 days due to a deterioration of the animal's condition He was alive at recovery, but died 12 hours later Immediately after recovery (prior to opening the capsule) atmosphere samples were taken for analysis, and after the cabin was opened, the trace gas adsorbents were removed for analysis These analyses, pathological evidence, and telemetered data all indicate that the decline of the flight animal was not due to toxic gases (ref 3)

The extensive test program that was conducted to ensure an acceptable spacecraft cabin atmosphere for the BIOSATELLITE III mission is described in this report, and the results of the tests and analyses are presented The conclusions drawn herein are restricted to the BIOSATELLITE III, but some general observations on the subject of closed atmosphere contamination are offered

DESCRIPTION OF BIOSATELLITE ENVIRONMENTAL SYSTEM

The BIOSATELLITE spacecraft cabin was a welded aluminum structure enclosing approximately 183 liters of free air volume in addition to the equipment and payload The nonmetallic materials within the cabin are listed in the appendices

The atmosphere control system (fig 1) was internal to the cabin except for the cryogenic oxygen supply, gaseous nitrogen supply, and metabolic water storage tanks which were in the adapter module Oxygen was supplied to replenish that used by the monkey The oxygen partial pressure was maintained between 135 and 165 mm Hg during orbital flight The total pressure was maintained at 760 ± 77 5 mm Hg by means of the nitrogen supply Nitrogen would enter the cabin only if the structure leaked, it is believed that no nitrogen was required during flight Carbon dioxide was removed by lithium hydroxide beds The downstream bed (can 2) would not be used until late in the mission, when it could be opened to air flow by the diverter valve (item 11 in figure 1) Carbon dioxide level was monitored during flight Trace contaminants were removed by an activated charcoal bed upstream from the LiOH beds The charcoal, U S Sieve number 6X12, was obtained from coconut shells, and had a packed weight density of 0 4 to 0 45 g/cc A trace-gas removal assembly containing Amberlyst (Rohm & Haas), molecular sieve and hopcalite removed ammonia, carbon monoxide, and other oxidizable compounds

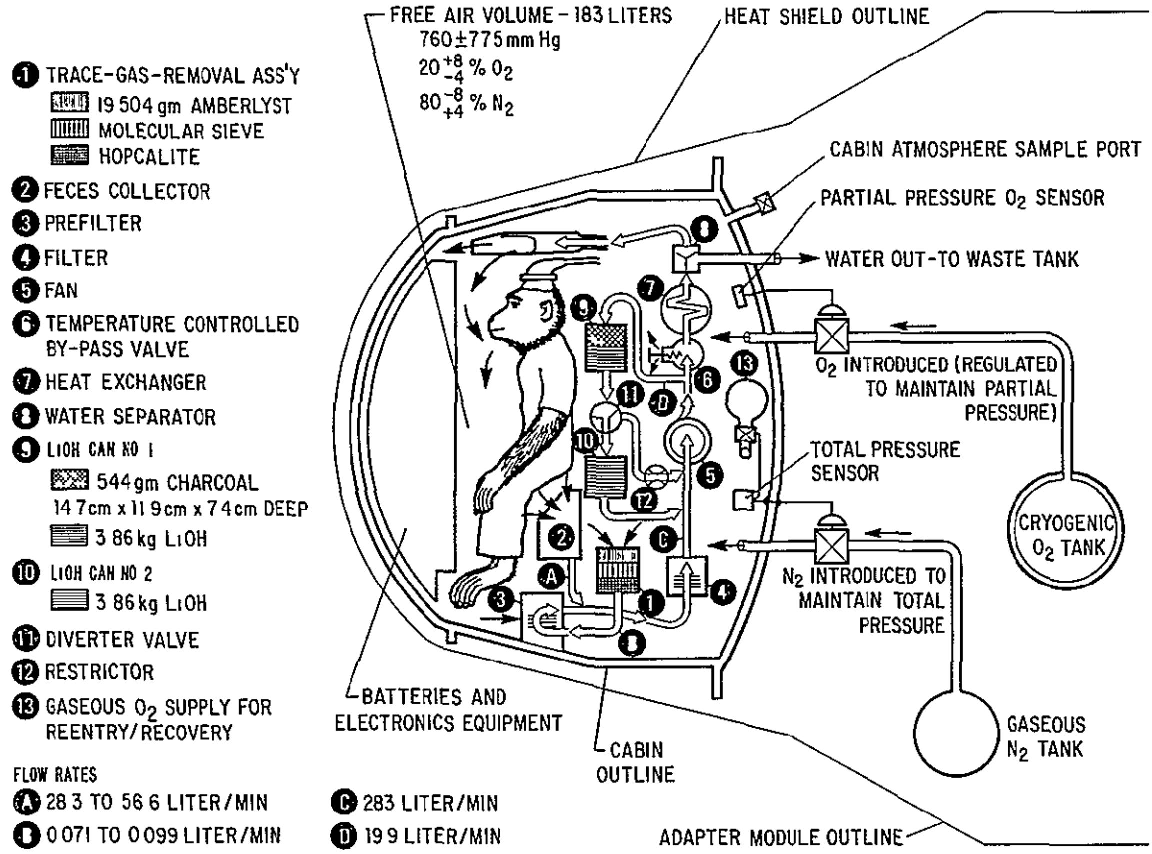

Figure 1 – BIOSATELLITE III environmental system

The cabin would vent to the outside only in case of an overpressure of 250 mmHg No other venting was planned until the atmosphere samples were taken after recovery

After separation from the adapter module, oxygen was supplied from a gaseous O_2 tank contained in the cabin (fig 1) The O_2 partial pressure during this period (maximum duration of ~ 7 hr) was expected to be about the same as for orbital flight, but a maximum range of 105 to 260 mm Hg was considered acceptable

SAMPLING AND ANALYSES

The followmg sample methods were used

1 "Grab" – An evacuated steel sample bottle was attached to the chamber or cabin via cleaned steel tubing, and the sample was drawn directly into the bottle For some samples, the lines were heated Some samples were pressurized by means of a Teflon-diaphragm pump Before the grab sample was taken, a false sample was taken, filling the steel line with cabin or chamber atmosphere Prior to their use, the sample bottles were cleaned by evacuation at high temperature Most were backfilled with clean helium and analyzed by gas chromatography to verify cleanliness before use The time between evacuation of the bottles and their use was minimized, and was never more than 72 hours (in most cases, less than 24 hr), except for the postrecovery samples for which the bottles had been evacuated as long as 3 weeks before use

2 Special grab – Hamilton gas syringes were used for samples intended for rapid determinations of carbon monoxide, ammonia, formaldehyde, ethylene oxide, oxygen, nitrogen, carbon dioxide, helium, hydrogen, and argon

3 Cryogenic trap – Concentrated samples were obtained by flow of the atmosphere through steel sample containers immersed in salted ice, dry ice, and liquid nitrogen (in that order) Flow was regulated by a pump and flow meter so that a record of the amount of gas sampled was obtained Steel tubing was used and was generally heated to insure that all contaminants reached the traps The samples were refrigerated in dry ice for shipment

4 Liquid nitrogen (LN_2) cryogenic trap – Same as (3) but only a single sample container immersed in liquid nitrogen was used This method was used when a carrier gas (N_2) was flowed through the sample in lieu of air

5 Hydrogen sulfide (H_2S) detector – A glass tube containing lead salts, provided by Mine Safety Appliances, was connected via a short stainless-steel tube to the atmosphere to be tested The sample was then drawn through the detector tube using a syringe to control the volume sampled Analysis of the sample was performed at the time of sampling by observing the degree of color change in the tube

6 Ammonia detector – This procedure was rarely used, but was generally the same as described for the H_2S detector The glass tube contained diketohydrindene hydrate and provided immediate analysis by observation of the location of the color change boundary within the material The method was developed and provided by the Naval Research Laboratory (ref 4)

7 Mercury detector – The sample was drawn directly into the instrument (Lemaire Instruments Type V Mercury Vapor Detector) through plastic tubing, and the mercury concentration was read directly The instrument could measure concentrations down to about 0 025 mg/m^3

8 Acid detector – The atmosphere was drawn or forced at a controlled rate through a known area of treated indicator paper supplied by the Naval Research Laboratory This method was sensitive to about 0 1 ppm for strong, hydrolizable acids

Each grab or cryogenic sample was analyzed by one of the following organizations

Aerojet General Corporation, Electronics Division, Analytical Research Laboratory, Azusa, California

Bendix Materials Control Laboratory, Kennedy Space Center, Florida

General Electric Reentry and Environmental Systems Division, Philadelphia, Pennsylvania, and Cape Kennedy, Florida

NASA Kennedy Space Center, Malfunction Investigation Branch

Naval Research Laboratory, Chemistry Division, Washington, D C

In addition to support from the agencies named above, special analyses were performed by the following

Air Force Eastern Test Range, Environmental Health Laboratory – Measurements of mercury concentration

Air Force Eastern Test Range Chemical Laboratory – Verification of the purity of gas supplied for flight

NASA Ames Research Center – Special ammonia and acid determinations

Stanford Research Institute, Palo Alto, California – Tests and analyses of one of the components of the spacecraft and of a contaminated fitting

Throughout the program it was found that careful attention to the cleanliness of sample fittings was essential Several samples taken through fittings that had not been specially cleaned or checked were found to have exceptionally high contaminant levels

Multiple samples were usually taken so that analyses could be made by several agencies No consistent attempt has been made in this report to compare analytical techniques or the results from different analysts Details of the analytical techniques are beyond the scope of this report, however, some of the techniques are identified

The grab and cryogenic samples were normally analyzed by both mass spectrometry and gas chromatography The gas chromatograph method, when used alone, may discriminate against certain compounds and thereby prevent their discovery For many tests reported herein, the sample was also introduced directly into a mass spectrometer Flame ionization and electron capture techniques were often used to identify hydrocarbons and chlorinated compounds, respectively Ammonia was quantified by wet chemical analysis using Nessler's reagent Formaldehyde was tested for by wet chemistry by either the Fuchsin aldehyde test or 3-methyl 2 benzothiazolone hydrazone hydrochloride (3 MBTH, ref 5), using a spectrophotometer to measure color change in the reagent However, neither of these methods was specific for formaldehyde, yielding instead the concentration of total aldehydes expressed as formaldehyde The 3MBTH test was equally sensitive to acetaldehyde, benzaldehyde, and formaldehyde The results are presented in the tables as

"formaldehyde" with an appropriate notation "Total hydrocarbons" were obtained from a calibrated flame ionization detector "Total chlorides," where reported, were obtained by the Naval Research Laboratory using a special microcoulometric detection system "Halogenated hydrocarbons," where reported, were measured by a special infrared absorption setup which was calibrated with a mixture of chlorinated standards including Freon 113 and trichloroethylene Hydrogen sulfide, mercury and acid determinations were made with the special detectors described previously Ethylene oxide was determined either by infrared or gas chromatograph methods Of the remaining compounds for which limits were established, only ozone and sulfur dioxide could not satisfactorily be determined in the atmosphere samples An attempt to detect ozone with a Mine Safety Appliance detector tube did not disclose ozone, but the level of concern for BIOSATELLITE (table 1) was below the sensitivity of this instrument The safe limits for dichloroacetylene (dichloroethyne), fluorophosgene (carbonyl fluoride), hydrogen fluoride, Mercury, monochloracetylene (chloroethyne), ozone, and phosgene were at or below the level detectable by the analytical techniques therefore, emphasis was placed on confirming absence of the precursors or sources of these materials

The limits placed on the BIOSATELLITE contaminants are generally below established toxic levels so as to minimize any effect on the animal's condition and thereby prevent an effect on the experiment The resulting requirements for atmosphere analysis were more stringent, and included more compounds than the analyses normally performed by some of the supporting agencies Since determining extremely small concentrations requires an extensive calibration procedure for each compound and a significant effort to reduce the instrument background, there was not sufficient time to develop the capability at each laboratory to quantitate small concentrations of all contaminants Consequently, for many compounds there was no specific analysis, and this is indicated by blanks in the tables The notation "ND" (none detected) in the tables of results indicates that the concentration was below background level for that compound For each "limited" compound, the background level for analysis of grab samples is provided in table 1 Where concentrations below the levels given in table 1 are reported, they are results from cryogenic, LN_2 cryogenic, or pressurized grab samples An ND for compounds other than those listed in table 1 should be interpreted in general as a concentration below 0 01 ppm Whenever more than one analyst provided a quantitative result for the same compound, only the highest concentration reported is given in the tables herein, the data, therefore, represent "worst case" conditions The only exception is the flight spacecraft recovery sample aldehyde level (see "Discussion" section)

The procedures used to desorb the charcoal samples were as follows

Time, hr	Temperature	Pressure, mm Hg
0 to 3	Ambient room	10^{-5}
3 to 8	Increase at 50° C/hr to 250° C	10^{-5}

Alternatively,

Time, hr	Temperature	Pressure, mm Hg
0 to 40 min	Ambient room increased at 4° C/min to 175° C	10^{-5}
40 min to 2 hr, 40 min	175° C	10^{-5}

The efflux from the sample container was fed directly into a cryogenic trap or series of traps The charcoal samples were essentially loose within the desorption chambers so that the effective bed depth was very small Completeness of desorption for the compounds of most concern has been checked for both methods, giving confidence that at least 90 percent of the adsorbed materials was recovered

DESCRIPTION OF TESTS AND PRESENTATION OF RESULTS

The investigations performed in conjunction with BIOSATELLITE III are classified (with letter designations) as follows

- A Closed spacecraft cabin tests
- B Tests of components in closed chambers
- C Tests of animals in a single-pass system
- D Single-pass tests of spacecraft CO_2 and trace-gas-removal assemblies
- E Adsorption tests of charcoal
- F Analyses of charcoal, LiOH and trace-gas-removal resin
- G Sample analyses of bottled gases supplied to spacecraft cabin and test chambers
- H Ambient atmosphere sampling and analyses
- I Other tests

The investigations are listed and described in table 2 and the results for some tests are presented in the notes For convenient reference, each test is designated by a letter and number The letters indicate the type of test as given above and the number identifies the specific test of that type Table 2 also indicates whether the equipment was operating during the test The numbers in the sixth column of table 2 identify the monkeys used in the tests A number was assigned by the experimenter and was used to identify all records and data applicable to a particular experimental animal Columns 7-12 are applicable mainly to the spacecraft cabin tests since they indicate whether certain items were included within the cabin Columns 13 and 14 tell whether external gas supplies were provided to the cabin or chamber and identify their source Column 2 of the second sheet of table 2 identifies the flush gas used The nonmetallic materials exposed to the atmosphere within the spacecraft cabin or the chamber during the test are listed in the appendixes noted in column 4 of the second sheet Column 5 of the second sheet gives the time period from cabin or chamber closure to the last sample taken (in the case of cryogenic samples, the time is the completion of the sample period) Column 7 of the second sheet gives the number of analysts who analyzed the samples

The spacecraft atmosphere was sampled from a special port in the aft cabin wall (fig 1) A short length of stainless-steel tube was used to connect the port to the sample bottle and was very carefully cleaned prior to use The sample port was sealed except during sampling or during flushing of the cabin The spacecraft was oriented with the cabin nose pointed up during sampling, therefore, the port was close to the bottom of the cabin

When the cabin or test chamber was flushed before test, the flush was continued until cabin/chamber closure so that the initial sample was largely the flush gas

The spacecraft charcoal/LiOH and trace-gas-removal assemblies (see fig 1) were normally sealed off from the cabin when not in use The polyvinyl chloride tubes leading to and from the assemblies were clamped, and the trace-gas-assembly inlet was covered During storage periods, the LiOH/charcoal cans were pressurized with nitrogen from a storage bottle to prevent the introduction of moisture and CO_2

The results of the investigations are presented in tables 3 through 10 except for tests E1, E2, F7, G, and H which are reported in the notes to table 2 Tables 3 through 7 and table 10 list the atmosphere concentrations of all of the compounds identified in each test The restricted compounds (those for which limits had been identified) are listed first, followed by a list of all other compounds that were found Table 7 presents the results of the limited analysis of the LiOH samples Table 9 gives the charcoal analysis results in terms of concentration per gram of charcoal No limits were set for the charcoal concentrations, but the format of table 9 is similar to the others with an additional list of compounds that were found only in the charcoal samples

DISCUSSION

General

The BIOSATELLITE atmosphere investigation concentrated on those materials which had previously been found in closed atmospheres and which were considered to be likely to affect the monkey's condition (refs 2, 6, 7, and 8) Particular attention was directed to toxicants that could be produced by reaction between commonly used volatile substances and materials in the spacecraft The best known of these are dichloroacetylene (refs 1 and 9) and phosgene, which can be produced by reaction of some chlorinated compounds with hydroxides Since the BIOSATELLITE used LiOH to remove CO_2, these compounds and their precursors were tested for with special care As it happened, of the highly toxic materials, dichloroacetylene and phosgene were the only ones for which evidence was found in any BIOSATELLITE test This evidence was found only in the charcoal and LiOH used during the prototype cabin test (test A1)

The only established precursor of dichloroacetylene is trichloroethylene, which is a commonly used degreaser, and was probably used during the manufacture of BIOSATELLITE components (see appendix A) Trichloroethylene was found in many of the test atmospheres, but the concentration was never high enough to produce a dangerous quantity of dichloroacetylene (realistic tests have shown that only about 1 gram of dichloroacetylene is produced per 10 grams of trichloroethylene) In addition, the trichloroethylene would have to pass through a charcoal bed to reach the LiOH (see fig 1) This charcoal was demonstrated by tests E1 and E2 (table 2) to be an efficient adsorber of trichloroethylene, even when other materials had already been adsorbed on the charcoal It must therefore be assumed that if chlorinated compounds were reacted in the LiOH bed, they must have been in the LiOH prior to installation in the cabin The reaction to form dichloroacetylene would not proceed at an appreciable rate until the start of exothermic reaction with CO_2 and water from the monkey

LiOH does not have a strong affinity for trichloroethylene or chloroform (a known precursor of phosgene) Therefore, it should be expected that, if a large amount of precursor compound were in the LiOH bed at the start of testing, a relatively large concentration should be found in the

atmosphere once the test was started, and a significant amount would be recovered from the charcoal after the test This set of conditions was never found therefore, probably very little trichloroethylene or chloroform was in the LiOH at the start of any test

Since dichloroacetylene was found in one charcoal sample and therefore appeared to be the most likely toxic hazard in BIOSATELLITE, 12 of the same type of monkey were exposed to it at the Naval Toxicology Unit in Bethesda, Maryland The results of this study showed that a concentration of 0 75 ppm would cause some illness within the first several days, but that at least 700 mg had to be breathed in order to cause the death of a healthy monkey From the evidence of dichloroacetylene existence in the BIOSATELLITE, the maximum amount of dichloroacetylene that could have been produced is less than 15 mg The amount that would cause degradation of a BIOSATELLITE monkey is not known because the effects of possible stress, induced by the invasive instrumentation of the monkeys prepared for the BIOSATELLITE mission, on the tolerance to toxic gas has not been established Also, nothing is known of the possible potentiation or synergistic effects of other contaminants in the BIOSATELLITE atmosphere, but the limits applied for many compounds were set low enough that such effects were probably minimized Dichloroacetylene is known to depress appetite (ref 9) and the animals at the Naval Toxicology Unit began to eat poorly soon after the tests began The toxin effect may therefore have been enhanced for these animals, and the exposure found to cause death may be lower than would be required under forced nutrition The flight and ground test animals (tests A8 and A1) consumed nominal amounts of food until the last few hours of the test periods, so that impairment of their appetites was not evident and they were also less likely to have been affected by potentiation of any toxin by poor nutrition

Prototype Spacecraft Atmosphere

The main purpose of this part of the study was to determine whether toxic gas caused or contributed to the illness and death of monkey 479 during test A1 Test A1 is described in table 2

The symptoms observed for monkey 479 during test A1 were comparable to those noted in men exposed to dichloroacetylene (ref 9) However, the pathological examination disclosed no evidence of kidney damage Autopsies by the Naval Toxicology Unit of animals that had died as a result of exposure to dichloroacetylene show severe kidney damage in every case The lack of kidney damage strongly indicates that dichloroacetylene was not the sole cause of the demise of 479, and could only have been contributory Existing information on the pathology of monkeys exposed to other toxic gases is insufficient, however, to establish with absolute certainty that this animal did not die from any toxin

The test results pertinent to the following discussion are presented in tables 3, 7, 8, and 9 for tests A1, D3, F1, and F4, respectively

Since the atmosphere samples taken during the first period of test A1 were not analyzed for most of the toxic compounds, there is no direct evidence of the existence of toxic gases or their precursors, except formaldehyde, during the time that monkey 479 was in the spacecraft As noted previously, the tests for determining formaldehyde were not specific but also reacted to other aldehydes therefore, the concentrations reported in table 3 are for total aldehydes The main

contributors to the reported aldehyde concentration are thought to be acetaldehyde and benzaldehyde, which could be produced by the animal, since there was no likely source of formaldehyde in the spacecraft Although formaldehyde had been used to sterilize the interior of the urine collection system in the spacecraft less than 48 hours before the start of this test, the urine system had been thoroughly flushed with distilled water after sterilization, and test of the final flush water showed no detectable aldehydes An additional discredit of this source is obtained from the fact that although no formaldehyde was introduced after the initial sterilization, the same concentration of aldehydes reappeared more than 18 days later (table 3, 264 5 hr sample) This is aldehyde concentration reported would not be toxic to the animal if only a small portion was formaldehyde

The only indications that dichloroacetylene and phosgene may have existed in the prototype spacecraft atmosphere were obtained from analyses of the charcoal and LiOH used during test A1 Dichloroacetylene, trichloroethylene, and chloroform were found on the outlet side of the charcoal (table 9, test F4) and phosgene was reported on the LiOH (table 8, test F1) Of these compounds, only trichloroethylene was found on the inlet side of the charcoal, and at a concentration less than found in unused charcoal (test F6, table 9) As previously discussed, the evidence indicates that the precursor compounds would have had to be in the LiOH at the start of the test The small amount of trichloroethylene found in the inlet side of the charcoal and the absence of chloroform indicates that only a small amount, if any, of precursor compound was in the LiOH at the time the cabin was closed since unreacted compounds should be "washed" off the LiOH into the atmosphere A possible maximum amount of dichloroacetylene that could have been present can be estimated from the results of test F4, by making the conservative assumptions that the measured concentration of 1 36 μg/g represents a 50-percent recovery of this material from the charcoal, that the same concentration existed throughout the charcoal and that animal 479 removed (reacted) 90 percent of the dichloroacetylene from the air, so that the amount reaching the charcoal represented only 1/10 of the total This calculation gives 10X2X1 36 μg/gX544 g = 14,800 μg of dichloroacetylene, which would correspond to an average concentration of

$$\frac{14{,}800\ \mu\text{g}}{12{,}480\ \text{min (occupancy by 479)} \times 19.9\ \text{liters/min flow through charcoal}}$$

$$= 0\ 06\ \mu\text{g/liter} = 0\ 015\ \text{ppm}$$

in the gas passing through the charcoal, assuming a constant removal rate by both animal and charcoal, and a constant production rate in the LiOH Alternatively, if all of this dichloroacetylene is assumed to have been in the atmosphere at the start of the test, the initial concentration would have been 20 8 ppm which would have been reduced to 0 001 ppm after about 1-1/2 hours by adsorption in the charcoal, neglecting removal by the monkey This total amount of dichloroacetylene, less than 15 mg, is considerably below the 700 mg required to cause death according to the Naval Toxicology Unit tests

Another source of information concerning the possible production of dichloroacetylene is the Cl^-content of the LiOH itself As can be seen in table 8, the used LiOH (test F1) has a slightly greater normalized Cl^-content than the unused sample (test F2) If the maximum difference of 2 5 ppm is assumed to result only from the reaction of trichloroethylene, about 2 mg of dichloroacetylene could have been produced Actually, the unused LiOH was from a different lot

and the difference in normalized Cl^- content is within the range of variation for fresh LiOH, the Cl^- content, therefore, should not be considered as evidence of the presence of a contaminant

The 1 ppm of phosgene found on the LiOH (test F1, table 8) cannot be related to an atmosphere content because the LiOH is not an adsorber and no information is presently available that relates the amount of phosgene produced to the amount retained on the LiOH Assuming no charcoal in the system and LiOH to be an adsorber of phosgene, a worst case calculation similar to that made for dichloroacetylene gives an average concentration of 0 04 ppm of phosgene for the amount of LiOH contained in one can (only the first can was used during the first two periods of test A1) The existence of a concentration of this magnitude would have been detected on the charcoal

A special test, D3, was run to determine whether any trichloroethylene remained on the surfaces of the fiberglass-resin LiOH cans that had been used during test A1 Although these cans had been cleaned and reloaded after test A1, it is believed that some trichloroethylene would have remained if it had ever been present in significant quantities To assist in driving off adsorbed materials, the surfaces of the cans were heated during the test (see fig 2), and the results (table 7) show only a trace (<0 00002 ppm) of trichloroethylene This result is considered as supporting evidence that very little trichloroethylene was ever in the cans, but is not conclusive

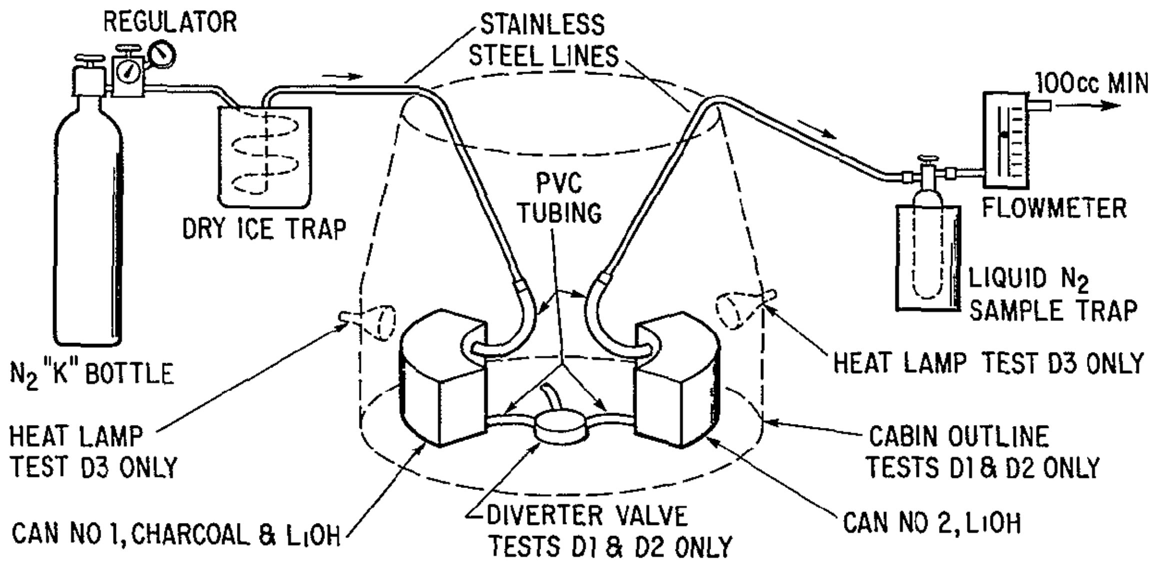

Figure 2 – Test setups for tests D1, D2, and D3

Two results of the gas sample analyses given in table 3 appear to suggest the existence of chlorinated hydrocarbons in the atmosphere during test A1 First, the sample taken at 180 5 hours of the second period showed a concentration of total chlorides obtained from the special microcoulometric analyzer of 6 9 mg/m^3, whereas summation of the compounds individually identified by gas chromatography gave a total of only 3 9 mg/m^3 Since dichloroacetylene is reported by the Naval Research Laboratory to be unstable on Porapak, which was the chromatograph column material, the additional amount of chlorides found in the microcoulometric system might have represented dichloroacetylene at a concentration of 0 77 ppm A concentration this high should be reflected by a greater concentration in the charcoal than was detected, especially

since the atmsophere sample was taken long after the sick monkey had been removed. The second result of interest is the concentration of 0.14 ppm of trichloroethylene reported for this same sample. This amount can only be construed as a short-term level or as a faulty sample because the maximum amount of trichloroethylene found in the charcoal for test F4 was only 0.44 μg/g, whereas if the atmosphere passing through the charcoal for 180 hours had contained 0.14 ppm of trichloroethylene, about 300 μg should have been recovered from each gram of charcoal according to the results of tests E1 and E2 (table 2).

The only potential source of trichloroethylene that has been identified for the prototype spacecraft is the heavy-particle dosimeter. Tests B3 and B3a (table 5) show that the original configuration of this unit, which was in the cabin with monkey 479, was a potential source of trichloroethylene and chloroform although the test conditions of reduced pressure and elevated temperature were more severe than the spacecraft-cabin conditions. The dosimeter apparently did not cause contamination of the atmosphere during test A1, since the charcoal did not adsorb significant quantities of either compound from the atmosphere.

There is inadequate information available on formation rates of contaminants and the amounts removed by adsorption on structural materials are unknown, therefore the contaminants found on the charcoal and LiOH in this study cannot be definitely related to atmosphere concentrations so as to determine conclusively whether toxic gases existed in sufficient quantity to cause or contribute to the illness and death of monkey 479. Direct evidence from gas sample analyses was not obtained during the critical periods when monkey 479 was in the spacecraft cabin. The hypothesis that appears to best satisfy the data is that small amounts of trichloroethylene and chloroform were in the LiOH prior to the start of the test. These compounds began reacting before the start of test A1 so that in the absence of airflow some dichloroacetylene diffused toward the charcoal and was adsorbed on the side closest to the LiOH (outlet of charcoal). The actual amounts released into the atmosphere during the test were probably well below that which would cause illness of a healthy monkey. No data are available to permit assessment of whether a mixture of low concentrations of several toxic gases could have contributed to the degradation of a monkey that was also subjected to other stresses such as restraint, restricted diet, partial isolation, and sensor implantation, as was the case for the BIOSATELLITE animals.

Flight Spacecraft Atmosphere

The main purpose of the entire investigation was to ensure that the flight spacecraft atmosphere would be free of contamination. Tests of the flight spacecraft prior to achieving the final launch configuration are reported in table 4 for tests A2 through A6. The charcoal used during test A2 was analyzed and the results are reported as test F6 in table 9.

The ground tests during which the spacecraft systems were operating (A2, A4, and A6) showed very low contamination levels, with a slight tendency for concentrations to build up during the test period. Chloroform, ethyl alcohol, the Freons, and 1,1,1 trichloroethane were the only constituents that showed consistent increases. No increase in concentrations occurred during test A2, which reflects removal by the charcoal bed since this was the only ground test of the flight spacecraft with the LiOH/charcoal loop open. The concentrations of contaminants were considerably higher in the charcoal used in test A2 (table 9, test F5) than in unused charcoal (test F6), indicating that, at the time test A2 was run, some contaminants had not been eliminated

from the environment The concentration of Freon 113 in this charcoal was 123 μg/g, which corresponds reasonably with 171 μg/g calculated from the atmosphere concentration of 9 5 ppm measured at 0 3 hour and assuming 100-percent removal in the charcoal Since the only sample analyzed was from the outlet side of the charcoal, the average concentration may have been closer to the calculated figure The animal used in test A2 showed no symptoms attributable to toxic gas during or after his 4-1/2-day exposure, which supports the gas sample evidence that the contaminant concentrations were below toxic levels

The static (nonoperating) flight cabin tests, A3 and A5, showed much higher concentrations of contaminants than the operating-spacecraft tests, and the increases during the test periods were generally greater, except for the 601-hour sample from test A5 However, the results of the 601-hour sample analysis are considered to be invalid, as explained in note 3 to table 2 The least reassuring results were obtained for the 240-hour sample from test A5, which showed trichloroethylene at 0 6 ppm and 1,1,1 trichloroethane at 0 66 ppm Unfortunately, the results of this analysis were not available until after launch, therefore, no search for the source could be made It is possible that there were sources of chloroform and trichloroethylene in the cabin during these tests, but the results are not given the credence accorded the operating-spacecraft measurements (tests A2, A4, and A6) because the cabin air was circulated during the latter tests

The decision to commit BIOSATELLITE III to launch was based primarily on the results of cabin test A6, which was run in the near-final configuration on the launch pad, and tests B4, C1, C2, D2, and D4 (see figs 2, 3, and 4), which provided information on components that were not

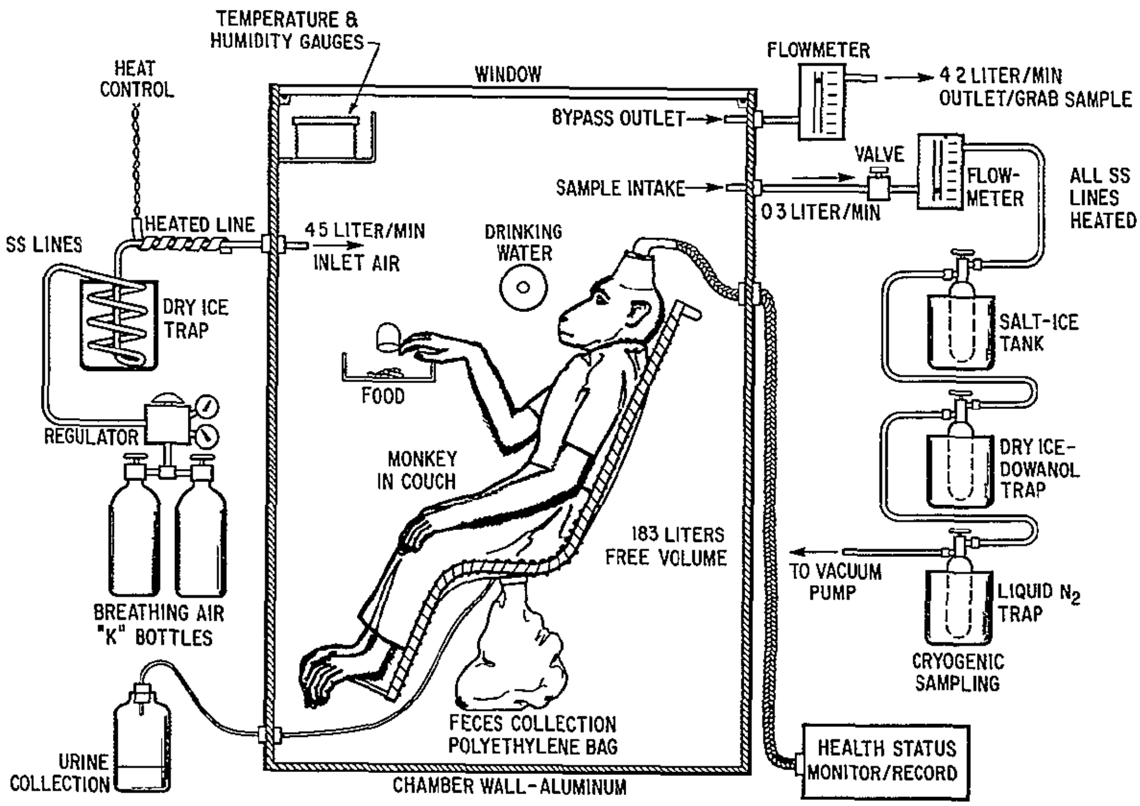

Figure 3 – Monkey tests, tests C1 and C2

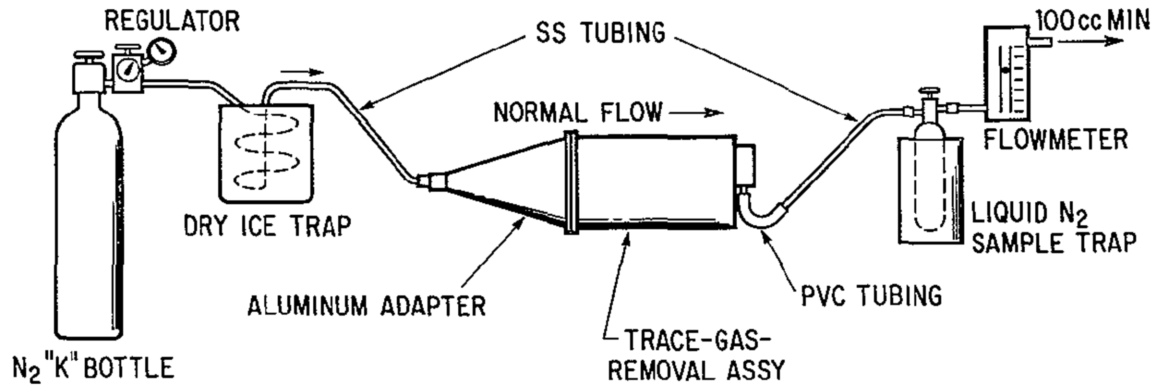

Figure 4 – Test setup for test D4

included or operated in test A6 Tests B6, E1, E2, and G3 yielded additional supporting information On the basis of these tests the spacecraft atmosphere was predicted to be satisfactory The prediction of the animal's contribution to the atmosphere from tests C1 and C2 was somewhat questionable because of the difference in the CO_2 and trace gas control arrangements As shown in figure 3, CO_2 and trace gas in the monkey test chambers was controlled by continuous dilution of the atmosphere by supply air The flow rate through the chamber was less than one-fourth of the flow through the charcoal in the spacecraft cabin, but stringent comparison of the rate of contaminant removal is not possible since the degree of mixing is not known for either system The most important observation pertaining to the monkey test results is that the animal could not have been a significant source of the compounds tested for because the concentrations of most compounds decreased after insertion of the animal in the chamber The heavy-particle dosimeter, which had shown a potential for contamination in test B3, had been redesigned and was satisfactory as demonstrated by test B4 The only flight component not actually tested in the study was the charcoal bed but the results of tests E1 and E2 gave high confidence that the charcoal would effectively remove trace gases from the atmosphere

Flight-readiness was confirmed by the results for the grab samples taken just after insertion of monkey 470 for launch These samples (test A7) showed only the aldehydes at a concentration above the safe limits The major contributors to the prelaunch aldehyde measurement are considered to be acetaldehyde and benzaldehyde, to which the test method would show significant reactions, and which were probably products of the animal The only potential source of formaldehyde is the urine system that had been sterilized with 8 percent formaldehyde in ethanol 2 days before insertion of the animal The system was flushed immediately afterward until the flush water contained no detectable aldehydes (tested by method of ref 5), and the urine system interior was always sealed from the cabin, therefore, formaldehyde contamination from this source seems unlikely

The actual flight results are given in table 4 for test A8, in table 7 for test F3, in table 9 for test F7, and in table 2 for test F8

The atmosphere samples taken immediately after recovery showed concentrations of ammonia, aldehydes expressed as formaldehyde, Freon 113, and trichloroethylene that were above the established limits and were higher than found in any other spacecraft closed cabin test The concentration of "halogenated hydrocarbons" was also high, but the analyst reported that this was

due almost entirely to Freon 113 therefore it need not be discussed separately In addition, apparent increases in concentration over the prelaunch samples were found for ethanol, isopropanol, total hydrocarbons, benzene, 2-butanone (methyl ethyl ketone), carbon monoxide, dichloromethane, chlorinated unknowns, dioxane, ethyl acetate, Freon 11, methane, 1,1,1 trichloroethane, sec-butanol, chlorotrifluoroethylene, ethyl benzene, furan, styrene, tetrachloroethylene and toluene, although none of these reached a high enough concentration, either singly or in combination, to cause concern The Freon 113 and trichloroethylene concentrations reported are below toxic levels since the safe limit for these compounds was based on possible toxic products of their reaction with LiOH Some of the samples taken after recovery in steel bottles are of questionable validity because the bottles had been evacuated for an excessively long time before use, and may therefore have been contaminated However, aldehydes, ammonia, carbon monoxide and methane concentrations could not have resulted from external contamination, therefore these results are considered valid Special detectors or gas syringes were also used to determine carbon monoxide, aldehydes, ammonia, ethylene oxide, and hydrogen sulfide and these determinations were therefore not affected by external contamination

Ammonia, aldehydes, carbon monoxide and methane are considered to have been produced mainly by the animal since the previous tests showed that the spacecraft and its components were not a likely source of these materials Methane and carbon monoxide will not be discussed further since they did not present a danger to the animal at the low concentrations reported

Ammonia was probably produced by breakdown of the fecal material trapped in the restraint garment as described in note 5 to table 2 This source would be more than sufficient to produce the concentration of 262 ppm found in one postflight steel sample bottle The effect of this amount of ammonia on a monkey has not been established, but it is below the level that would irritate the human throat A private communication from the National Academy of Sciences Toxicology Advisory Center indicates that this concentration would not create stress in a healthy animal beyond minor eye and respiratory irritation To provide a further indication of the amount of ammonia that had been in the atmosphere, the Amberlyst resin from the trace-gas-removal assembly was analyzed for ammonia content (test F8, table 2) An unused sample was not available to provide a baseline, therefore, the total amount found in the resin is assumed to have come from the spacecraft atmosphere The total 0 44 g of ammonia found in the resin is estimated to have been removed from about 1271 liters of gas passing through the resin at the average flow rate This indicates an average concentration of about 495 ppm, which is just above the threshold for throat irritation (but below that for eye irritation) in man The production rate from fecal breakdown and the flow rate through the resin are not well established and could affect this figure by an unknown amount (± 20 percent for flow rate alone) This large amount of ammonia found in the trace-gas-removal assembly is believed to result from the proximity of the unit to the fecal material, which was 6 to 9 inches from the intake From a gas syringe sample, the recovery ammonia concentration was measured at 35 ppm by the same wet-chemical technique used for the steel sample bottle No reason for the discrepancy is known, but since the 262 ppm value is more nearly compatible with the result of the Amberlyst analysis, this concentration figure is accepted as representative of the actual cabin atmosphere near the end of flight The charcoal was also found to contain 49 5 μg/g of ammonia (table 9, test F7), which is equivalent to 0 11 ppm in the atmosphere, however, this figure is not considered useful for establishing a cabin concentration level because charcoal is a poor adsorber of ammonia

The aldehyde concentration (expressed as formaldehyde) is open to question because of differences between the results from the various samples and from the different analytical methods The 0 84 ppm concentration reported in table 4 was obtained from a gas syringe sample by the method of reference 5, this is the same procedure used to obtain the other concentration values reported in tables 3 and 4 Analysis of a steel sample bottle content by the Fuchsin test after washing down the bottle contents gave a concentration of 50 3 ppm as formaldehyde From this same sample, mass spectrometric analysis showed acetaldehyde = 0 002 ppm, benzaldehyde = 0 005 ppm, and formaldehyde = 0 007 ppm, but the mass spectrometer had a gas chromatograph upstream of the inlet which could have trapped some of the sample, preventing it from reaching the spectrometer Analysis of another steel-bottle sample by the Fuchsin method gave 17 1 ppm total aldehydes as formaldehyde Finally, the charcoal content (test F7, table 9) showed concentrations of acetaldehyde, benzaldehyde, and formaldehyde of 0 27 μg/g, "None Detected," and $<$ 0 01 μg/g, respectively, assuming that the lower figure for formaldehyde in table 9 is more nearly correct since both were below the limit of quantification These aldehyde concentrations are within the adsorptive capability of the charcoal (refs 10 and 11) and can be converted to average atmosphere concentrations of acetaldehyde, 0 0003 ppm, benzaldehyde, $< 10^{-6}$ ppm, and formaldehyde, $<$ 0 00001 ppm Unfortunately, the analysis of the charcoal desorbate again used a mass spectrometer which had a chromatograph column upstream of the inlet, so that some of the material may not have reached the spectrometer In view of these contradictory results, it is necessary to look for other evidence to indicate the actual environment First, if the entire amount of aldehyde is assumed to be formaldehyde at a concentration of 0 84 ppm (or even 50 3 ppm), the animal would have shown some choking response during flight and severe lung and bronchial edema and damage to lung tissue would be evident in the autopsy In-flight telemetry showed no evidence of choking, and the autopsy showed an unimpaired respiratory system This evidence is comparable to that for the prototype spacecraft test, wherein there was a similar concentration of "formaldehyde" at various times during that test, as measured by the same analytical technique (table 3) Animal 479 showed some arrythmic breathing during test A1, but no choking Autopsy (the animal died 7 days after the test) showed recent minor hemorrhaging of the lungs Animal 453 showed no breathing anomalies during test A1, and upon his death 3 weeks after completion of the test, autopsy showed lung hemorrhaging which was too recent to have resulted from exposure to formaldehyde during the test

Another consideration is whether there could have been a large source of formaldehyde within the spacecraft The sterilization of the urine system before flight has already been described and seems to be an unlikely source Also, the urine system was tested for leaks after recovery and none were found It should also be noted that the urine system was sterilized before test A2 and no aldehydes were detected during that test (table 4) None of the other spacecraft tests for which aldehydes were measured showed the presence of a significant aldehyde source except when an animal was in the spacecraft The wet chemical techniques used are known to react with all aldehydes and may also react to ketones and amines that might result from animal metabolism or fecal breakdown Since the evidence indicates that the major portion of the measured aldehydes was probably not formaldehyde, it seems likely that metabolic products of the animal were the primary constituents, the rate of production may have become large as the animal's condition deteriorated Aldehydes other than formaldehydes would not pose a threat to the flight animal's health at the concentrations indicated

The relatively high concentrations of the compounds other than ammonia, aldehydes, carbon monoxide, and methane, that were found in the recovery gas samples, are felt to be

unrepresentative of the atmosphere levels due to improper handling of the sample bottles As mentioned previously, the bottles had been evacuated for as long as 3 weeks before use During this time they were stored in containers packed with styrofoam, which is known to adsorb volatiles, therefore any leakage could introduce contaminants from the packing into the sample bottle In addition, the quick disconnect fittings were cleaned with Freon 113 just before attachment to these bottles, and a planned vacuum-outgassing was not performed prior to the unexpected early return of the spacecraft Bottle and/or fitting contamination and/or nonuniform sample sizes due to vacuum loss is illustrated by the following comparison of concentrations of several compounds, listed in the sequence in which the samples were taken (analysis of each sample was by a single analyst)

Sample sequence	Freon 113, ppm	Trichloroethylene, ppm	Dichloromethane, ppm	Acetone, ppm
1	18 5	0 018	0 014	0 26
2	160	0 90	0 30	No test
3	5-10	0 05	ND	ND
4	31 2	Trace ($<$0 0002)	Trace ($<$0 0003)	1 2
5	98	No test	No test	1 1
6	8 0	0 12	0 48	0 32

This wide random variation cannot be attributed to analytical technique differences and is therefore considered to be indicative of differences in the samples The possibility that the sample bottle container could have been a source of contamination to a leaking bottle was investigated by taking a grab sample from the container atmosphere in test J3 As can be seen from the results in table 10, if the sample bottles did leak, they could have been contaminated by an atmosphere containing most of the same compounds as reported for the recovery sample The quick disconnect used to take sample 6 was tested for contamination The results of this test, J1, given in note 15 of table 2, show that some contamination did exist which would affect the recovery samples

The charcoal samples from the flight (test F7, table 9) were found to contain all of the same compounds except chlorobenzene, dichlorobenzene, C_1–C_5 hydrocarbons, and tetrachloroethane that were found in the gas samples, indicating that these compounds actually existed in the cabin atmosphere and were not only the result of external contamination of the gas samples However, the atmosphere concentrations calculated from the charcoal concentrations are less than the gas sample results, giving further indication that the steel bottles and their fittings were contaminated Although the flight charcoal analysis (test F7) revealed the presence of many contaminants, the most significant result is the absence of the most dangerous contaminants The total load of contaminants is high relative to that found in the other charcoals tested but it is far below the ultimate capacity indicated by the charcoal adsorption tests E1 and E2 and by analysis, according to reference 10 None of these concentrations implies a significant atmosphere content For example, the maximum concentration of trichloroethylene in the flight charcoal corresponds to an average concentration of only 0 0004 ppm in the atmosphere flowing through the charcoal, assuming that this charcoal originally contained no trichloroethylene

The possibility that contaminants on the flight charcoal were introduced prior to flight must also be considered The charcoal was installed in the spacecraft for approximately 104 days prior to launch During most of this time, a positive pressure of nitrogen gas was maintained inside the LiOH cans, but there were periods of days when transfer of air between the can interior and surrounding air could occur Also, the nitrogen used to pressurize the cans was obtained from bottled gas and

could have contained some contaminants, as shown by test G2 (table 2) When the cans were "sealed" from the atmosphere, but not pressurized with N_2, the inlet side of can 1 was not closed and therefore some additional diffusion of contaminants into the can could be expected Contaminants so introduced would be adsorbed on the charcoal, and probably minutely on the LiOH and the container walls

As part of the investigation to assess the flight spacecraft cabin atmosphere, the flight LiOH was analyzed for $C\ell^-$ content The results of this analysis, presented in table 8 as test F3, show that the normalized $C\ell^-$ concentration for the inlet of the first LiOH can is higher than for the other (downstream) samples, and that the agreement between the other samples is extremely good The difference in $C\ell^-$ level of 7 ppm on approximately 1418 g of LiOH could indicate a very large amount of dichloroacetylene produced (970 mg) if all of the $C\ell^-$ is assumed to result from reaction of trichloroethylene This seems unlikely since no dichloroacetylene was found in the charcoal or in the gas samples Unpublished data for another spacecraft show levels of normalized $C\ell^-$ of 140 to 160 ppm on used LiOH with no evidence of dichloroacetylene production Trichloroethylene is therefore not considered a likely source of the $C\ell^-$ found in the BIOSATELLITE III LiOH The $C\ell^-$ levels for the downstream (unused) flight LiOH samples were 6 ppm higher than for the unused LiOH in test F2, and this provides evidence that a chlorinated compound reached the LiOH before launch The LiOH in tests F2 and F3 (flight) was from the same production lot and was supposedly handled the same until installation in the LiOH cans Freon 113, which was found in the spacecraft during tests A3 and A5, is a likely candidate for a preflight reactant Tests D1 and D2 showed that very little unreacted chlorinated material was in the LiOH (table 7) during the flight preflight period

The only other data obtained that are pertinent to determining if a toxic condition existed in the flight spacecraft are the results of autopsy of the flight animal, referred to in reference 3 These results showed the absence of lung lesions that could have resulted from a number of toxins, and the absence of kidney damage that would be characteristic of dichloroacetylene poisoning

None of the tests conducted in this investigation indicated that the flight spacecraft cabin atmosphere had contained the two toxic materials of most concern, dichloroacetylene and phosgene Other contaminants were identified, but without strong evidence that they were present in sufficient quantity to have a harmful effect on the monkey

General Observations

The BIOSATELLITE III atmosphere investigation was hampered by a lack of basic information on the source and persistence of contaminants and on the adsorption efficiency of structural and "scrubbing" materials, and of parametric information on the relationships of source, chamber size, time, and concentration This information is required to effectively design and test an enclosed atmosphere to assure freedom from contaminants, especially as closed atmospheres are operated for longer durations and as new materials are employed The potential synergistic effect of a large spectrum of trace contaminants during a long exposure will dictate greater rigor in reducing all trace materials to a minimum, because it will be impossible to establish the toxicity of so many combinations of materials Information available on presently used materials is not useful except as a general guide to selection, because none of the tests established production or "offgassing" rates, and they are generally not referenced to concentrations as low as those of concern for BIOSATELLITE (cf ref 6)

The BIOSATELLITE material selection was generally good. For instance, most wiring insulation was polyvinylidene fluoride instead of polyvinyl chloride. However, there was extensive use of polyvinyl chloride tubing, nylon webbing, and foam plastic, all of which are ready adsorbers. White vinyl-backed tape (tested in test J2) was used extensively for insulation repair and chafe protection, and this may have contributed some trace materials. The materials listed in the appendices were carefully reviewed against the available information, or were found to be acceptable by test. A careful study of actual or potential heat sources was made in order to assure that none of the nonmetallics (especially nylon, teflon, viton) could be inadvertently heated to a temperature that would cause release of breakdown products. Electromechanical devices were reviewed for likelihood of ozone production, but no actual ozone production data were obtained and the olfactory sense was therefore heavily relied upon.

Several of the tests reported herein served to illustrate that, for BIOSATELLITE, externally introduced contamination was at least as important as intrinsic outgassing products from the spacecraft materials themselves. For instance, the results of tests D1 and D2 of the LiOH cans (table 7) show that the cans were effectively flushed by test D1 so that the total contaminants found during test D2 was dramatically less than for the earlier test. Similarly, test B5 of the food dispenser served to "outgas" the unit and the second test, B6, of the same unit showed much lower contaminant levels except for ethanol (table 5). The ethanol level increase resulted from a longer exposure of food pellets to the chamber atmosphere (see table 2); the pellets were found to be a source of ethanol by a special test not reported herein.

Prevention of external contamination was effectively practiced for BIOSATELLITE III, but it was not an easy task. Chlorinated and aromatic hydrocarbons are ubiquitous in all phases of manufacturing and operational activity. Trichloroethylene is widely used, and for BIOSATELLITE, some adhesives, cleaning compounds, and the launch vehicle engine flush had to be changed to eliminate its use. Even the gantry air-conditioning was found to be a potential problem (note 5 to table 2). The cleaning materials commonly used during manufacture, listed in appendix A, were a potential source of dangerous contamination prior to inception of the careful control. It is apparent that contamination of spacecraft materials must be stringently avoided starting with manufacture of the material itself.

Another serious contamination problem uncovered by the BIOSATELLITE test program is the prevalence of chlorinated hydrocarbons, and especially trichloroethylene, in bottled gases that are intended for use in atmospheres occupied by humans. The normal analyses performed for lot acceptance of such gases do not identify the presence of materials that should be of serious concern for long-term exposure. Existence of chlorinated hydrocarbons in gas bottles may also imply that such contaminants are frozen in the cryogenic supply tanks from which the gas is taken. Experience indicates that this is a potential source of contamination that should not be overlooked.

The BIOSATELLITE experience suggests that the only way to assure that a closed environmental system is safe for long-term occupancy by man or by biological specimens is through a carefully designed test program of the cabin elements and by careful control of materials. The basic test program should be augmented by plans for more detailed testing in the event that serious contamination is found. The BIOSATELLITE contingency plan called for (1) testing of components that might be sources of the contaminant(s) based on the materials list for the components, (2) retesting the spacecraft after the chief suspects were removed, and (3) testing of substitute or redesigned components prior to placing them in the spacecraft.

The list of restricted compounds for BIOSATELLITE III may be helpful, along with references 2, 6, and 8, in establishing a starting point for other agencies faced with the need to specify closed atmosphere cleanliness The BIOSATELLITE restricted-compound safe limits should be considered as applicable only to a Macaca nemestrina for an extended duration (greater than 30 days) Depending on the materials to be used in the enclosure, other compounds not included in this list, such as tolylene diisocyanate, toluene, and tetrachloroethane may be of concern Some of the compounds on the BIOSATELLITE list might also be deleted For example, 2-methyl butanone, ethylene glycol, hydrogen sulfide and ethylene oxide were never found in BIOSATELLITE atmospheres Fluorophosgene (carbonyl fluoride), phosgene, monochloroacetylene and dichloroacetylene are considered to be requisites on any list because of their extreme toxicity

CONCLUDING REMARKS

An extensive investigation performed to assure that the atmosphere of the BIOSATELLITE III spacecraft cabin would be safe for occupancy by a 6 4 kg Macaca nemestrina for the planned flight duration of 30 days established the basis for commitment to launch the spacecraft The study revealed some areas of uncertainty that were not completely resolved, such as whether or not contamination of the spacecraft atmosphere caused the deterioration of the first monkey during the prototype spacecraft ground test The study also identified the need for basic information on sources of toxic gases and on the control of contamination in a small closed environment

The results of the investigation are summarized as follows

1 Toxic gases in the cabin atmosphere of the prototype spacecraft may have contributed to the illness of the first monkey used in the system ground test, but available evidence indicates that the concentrations were insufficient to be the sole cause of illness

2 Extensive tests of the flight spacecraft cabin atmosphere during launch preparation assured that the atmosphere contaminant concentration during flight would be below levels that would affect the animal's health, and that compounds known to be highly toxic were not present above the limits of detection Data from these tests supported the decision to launch the spacecraft

3 Evaluation of the cabin atmosphere of the recovered spacecraft indicated that contaminants were within the tolerance levels of the flight animal

4 Parametric design data are needed on the concentrations of contaminants in an enclosed atmosphere as functions of material, source size, time, and enclosure volume Information on the absorption and desorption characteristics of nonmetallic materials is necessary to allow the most effective design of enclosed atmosphere control systems This information is of special concern for long-term space missions where very low concentrations are important Additional information is needed on the contribution of animal metabolism in order to permit the design of adequate atmosphere contaminant removal systems

5 Contamination problems in an enclosed atmosphere can be minimized by careful materials control considerations starting with the design stage and continuing through all phases of fabrication, assembly, test, and operations

6 External contamination as well as contamination from materials used in fabrication can cause serious problems in developing an enclosed atmosphere safe for occupancy by biological specimens

7 Vacuum outgassing of repair or replacement materials is an effective method of eliminating contaminants

8 BIOSATELLITE III experience demonstrated the need for a testing regimen similar to the one performed in order to assure that contaminant concentrations are well below levels that might be toxic for the organism in the system

9 Experience in the BIOSATELLITE III test program showed that high quality bottled gas supplies were frequently contaminated Specific bottles to be used for carrier gases and breathing supplies should be checked for trace contaminants

10 More data is needed on the physiological effects of long-term exposure to low levels of combined contaminants on organisms that are to be considered for spaceflight or for long-term inhabitance of any enclosed atmospheres The most urgent need is obviously for human data

Ames Research Center
National Aeronautics and Space Administration
Moffett Field, Calif , 94035, Oct 1, 1970

APPENDIX A

LISTING OF SPACECRAFT CABIN NONMETALLIC MATERIALS
Includes materials listed in appendix G

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Acetal	Thermosetting resin		E I DuPont	Delrin	Urine system, pellet feeder, gas management assembly
Acrylic	Adhesive	Mil A 8576	Rohm & Haas	PS-18	Light assembly 47C138 704
Acrylic	Structural plastic		Rohm & Haas	Plexiglass 11 UVA	Urine system
Acrylic	Structural plastic	Mil P-80B	E I Dupont Rohm & Haas		Gas management assembly
Acrylic	Structural plastic		E I DuPont	Lucite	Fiber optics
Alkyd	Alkyd primer	47A101933	E I DuPont	Preparakote primer 65 3010	Structure assembly
Alkyd	Adhesive		General Electric	GE7526	Timer, water dispenser 47D175532, terminal board assembly 47B116950
Alkyd	Varnish		Sterling Varnish	U 87	Gas management assembly
Buna N	Synthetic elastomer		Parco	4200 70	Urine system
Buna N	Synthetic rubber		Parco	488 70	Urine system
Buna N	Synthetic rubber		Parker Seal Co	214 N 304 7	Gas management assembly
Buna N	Synthetic rubber	MS 28775	Parco Rubber	483 70	Structure assembly
Buna N	Seal		James Pond Clark		Relief valve 47D168396

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Buna N	Synthetic rubber		Parker Seal Co	2 14 N 304 7	Gas management assembly
Buna N	Synthetic rubber		Parker Seal Co	N 299 5	Urine system
Buna N	Diaphragm		Bellofram	4 175 106 CBK	Water dispenser 47E 187857, urine system
Butyl, rubber	Synthetic rubber		Parker Rubber	B 318 7	Gas management assembly
Castor oil	Oil		Baker Chem		Urine system
Cellulose	Marking ink		State Stamp Works	977-9	Gas management assembly
Cellulose	Filter		Millipore Filter	White, AP10, 03700	Gas management assembly
Cellulose/ester	Filter		Millipore Filter	WHWP filter	Gas management assembly
Cellulose ester/ alkyd resin	Adhesive	147A1218	General Electric	Glyptal	Pellet feeder
Chlorofluorocarbon	Grease		3M	KEL F 90	Urine system
Chlorofluorocarbon	Porous Kel F	165A4429	Pall Corp	Kel F	Feces container
Chlorofluorocarbon	Fluoroelastomer		3M	Kel-F	Urine system, feces container, gas manage ment assembly
Chlorofluorocarbon	Lubricant		Hooker Chemical	Fluorolube	Gas management assembly

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Chlorofluorocarbon	Lubricant		Hooker Chemical	Fluorolube LG 100	Gas management assembly
Chloroprene	Adhesive		Goodyear		Gas management assembly
Chloroprene	Adhesive	147A1299T42	3M	EC1357	Container assembly 47E187340, water dispenser, 47E187857, feces container, pellet feeder
Chloroprene	Adhesive	147A1299	B B Chem Div	Bostik 1142	Feces container, couch assembly 47R147322
Chloroprene	Synthetic rubber	MIL-R 6855 C1 II, Type 20	Stockwell Rubber		Feces container
Chloroprene	Chloroprene/ aluminum cloth		Metex Electronics		Gas management assembly
Chloroprene	Synthetic rubber	ASTM-D735 SC-712, BE,E3, F2	Parker Seal	C 526 7	Gas management assembly
Chloroprene	Synthetic rubber		Stockwell Rubber	7465	Pellet feeder
Cyanoacrylate	Adhesive		Eastman Chem Products	Eastman 910	Biomedical tape recorder, gas management assembly
Diallyl Phthalate	Resin		Milton Ross Co	52 01	Gas management assembly
Diallyl Phthalate	Resin	MIL-M 14SDE	Milton Ross Co		Gas management assembly
Epoxy	Lacquer		Dennis Chem	Denflex	Biomedical tape recorder 47C137272

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Epoxy	Epoxy paint	47A101931	Finch Paint & Chemical Co	CAT A LAC 463 3-100	Air plenum diffuser duct, couch assembly 47R197322, trace gas assembly 47C139234, housing assembly 47C139233, base 47C139222, cover inlet 47C140044, regulator assembly 47C1376721, feeder assembly 47B114796, water dispenser 47E18757, pellet feeder 47B114796, water dispenser 47E187857, camera, prefilter shielding assembly 47D173205, structure assembly
Epoxy	Casting resin	R6388	Emerson & Cuming	StyCast 2651	Gas management assembly, wire harness
Epoxy	Epoxy fiberglass	47A101715P1	Cordo Mfg	Cordo Preg E 293	Foot rest and separator 47E190829, structure assembly, air plenum diffuser duct
Epoxy	Epoxy resin	47A101722	Rezolin luc	Epolite III	Foot rest and separator 47D173202, 47E190829, structure assembly
Epoxy	Epoxy resin		Shell Chemical	Epon 820	Gas management assembly
Epoxy	Epoxy potting compound		Epoxylite Corp	Epoxylite 3101	Camera

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Epoxy	Adhesive	165A4411P1	Emerson & Cuming	Ecco Bond Solder 57C	Structure assembly
Epoxy	Epoxy coating		Shell Chemical	Epon 815	Gas management assembly
Epoxy	Epoxy resin	MIL-I-46058A C1 A, TyER	Hysol	PC 12 007 A & B	Gas management assembly
Epoxy	Epoxy potting compound	147A1829	General Electric Re-Entry Systems	MPC-52	Converter controller 765D210, board assembly, 47C168450
Epoxy	Epoxy potting compound	147A1290P1	General Electric	MPC-12S	Component board assembly 765D209, module 47D170865, module 47D170893, module 47D175055, module 47D170894, module 47C141003, reentry vehicle inverter 47E188594
Epoxy	Epoxy filler paste	147A5474	Bloomingdale Rubber	Corfil 615	Foot rest and separator 47D173204G 1, structure assembly
Epoxy	Epoxy casting compound	156A9738	General Electric	M&P50	Foot rest and separator 47D173204G 1
Epoxy	Adhesive, catalyst	R6301P1 R6301P2	Armstrong Cork	J1170 1/ E 18-1	Couch assembly 47R147322, feces container
Epoxy/glass	Laminate	47A101715P1	Ferro	Cordopreg E 293	Feces duct 47D172039

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Epoxy	Adhesive	R6432	Hysol	Epoxy Patch Kit 615	Structure assembly
Epoxy	Potting compound	128A5471	Hysol	R8 2038/3475	Module explosive switch 248E251
Epoxy	Potting compound	47A101745P2	3M	Scotchcast 281	Recovery programmer 47E182584
Epoxy	Adhesive		Hardman	Epoxy 3358	Feces container
Epoxy	Epoxy resin	128A5454	Shell Chem Co	Epon 828/LP3, Teta, Deta	Air plenum diffuser duct biomedical recorder, gas management assembly
Epoxy/glass	Laminate	MIL-P-18177 Type GEE	General Electric	Textolite 11546	Water dispenser 47E187857, camera con troller 47E188580, structure assembly
Epoxy/glass	Laminate	MIL-P 15037	General Electric	Textolite 11588	Insulating filler 47B111832P1, inflight disconnect spacer 47B111833, structure assembly
Epoxy	Potting compound	156A9727	3M	Scotchcast 8	Illuminator assembly 47C143901, transmitter telemetry 47C137113, recovery beacon 47D167098, reentry vehicle power controller

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Epoxy	Potting compound	156A9727	3M	Scotchcast 8	Container assembly 47E127340, recovery programmer 47E182584, reentry transmitter, feces container, structure assembly
Epoxy	Potting compound	156A9727	3M	Scotchcast 9	Illuminator assembly 47C143901, transmitter telemetry 47C137113, light assembly 47C138704, reentry vehicle inverter 47E188594, camera con troller 47E188580, reentry transmitter, feces container, structure assembly, reentry vehicle power controller
Epoxy	Potting compound	156A9727	3M	Scotchcast 10	Telemetry transmitter 47C137115, reentry vehicle power controller, regulator assembly 47C137672, recovery programmer 47E182584, reentry transmitter, feces container, structure assembly
Epoxy	Adhesive		Bloomingdale Rubber	FM1000	Structure assembly
Epoxy	Epoxy primer	147A1279	Bloomingdale Rubber	BR227	Structure assembly

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Epoxy	Potting compound	146A9336	General Electric	A 3	Module explosive switch 288E251
Epoxy	Adhesive	R2830P1	Electro Science Lab	2209 A/B	Telemetry transmitter 47C137113, recovery beacon 47D167098, reentry transmitter 47C137113
Epoxy	Potting compound	R6341P1	Emerson & Cuming	ECCO Foam EFF 11	Telemetry transmitter 47C137113, reentry transmitter 47C137113
Epoxy	Potting compound	R63074P4	Emerson & Cuming	Stycast 1090	Recovery beacon 470D167098, gas management assembly, reentry transmitter, transformer
Epoxy/glass	Laminate		New England	GEE, GR 10	Gas management assembly
Epoxy	Epoxy coating		Chemical Coating	60 294	Gas management assembly
Epoxy	Epoxy resin	128A5474	Shell Chemical	Epon VIII	Air plenum diffuser duct (A Cat), gas management assembly, SV 715680
Epoxy	Epoxy resin	128A5474	Shell Chemical	Epon VI/A, DTA	Gas management assembly SV 715680,731700
Epoxy	Epoxy resin		Hysol	C9 4210	Gas management assembly
Epoxy	Epoxy resin		Furane Plastics	Furane 233-40	Gas management assembly
Epoxy	Epoxy resin		Hysol	15 017	Gas management assembly

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Epoxy	Epoxy resin	R6388	Emerson & Cuming	Stycast 2651	Multicoder 47C138100
Epoxy	Epoxy resin		Rubber & Asbestos	Bond Master M654	Gas management assembly
Epoxy	Resin		Shell Chemical Co	Stycast 1090/11	Gas management assembly
Epoxy	Epoxi patch kit		Hysol	0151 (Clear)	Gas management assembly
Epoxy	Epoxi patch kit		Hysol	0127 (Yellow)	Gas management assembly
Epoxy	Potting compound	R6322	Emerson & Cuming	Stycast 2850	Temperature sensor
Epoxy	Epoxy adhesive		3M	EC711	Pellet feeder
Epoxy/glass	Laminate		Perkin Elmer	G 10	Gas management assembly
Epoxy	Conductive adhesive		Emerson & Cuming	EccoBond 60L	Biomedical tape recorder
Epoxy	Adhesive	165A4434P1	3M	EC2216	Prefilter assembly 47D172324, camera assembly 47C140501, trace gas assembly 47C139234, filter 47B113616, structure assembly, gas management assembly, wire harness
Epoxy	Adhesive	165A4430P1	Shell Chemical Co	EPON 934	Filter shielding assembly 47A173205G1, structure assembly

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Ester	Grease		Humble	Beacon no 325	Pellet feeder
Ester	Grease		Shell	Aeroshell no 7	Pellet feeder
Ester	Lubricant		Anderson Oil Chemical Co	Winsor Lube L-245X	Camera
Ethylene propylene	Elastomer		Parker Rubber	E-515 8	Urine system
Fluorocarbon	Fluoroelastomer	MIL-R 25897D	E I DuPont	Viton B	Flexible guide light, urine system
Fluorocarbon	Fluoroelastomer	MIL-R 25897, Tyl C12	E I DuPont	Viton	Gas management assembly SV 731700
Fluorocarbon	Viton		Parco	975 60	Urine system
Fluorocarbon	Fluoroelastomer		R E Darling	Viton B	Structure assembly
Fluorocarbon	Fluoroelastomer		Parker Seal	77 545	Gas management assembly
Fluorocarbon	Fluoroelastomer		E I DuPont	Viton	Fiber optics
Fluorocarbon	Fluoroelastomer		Conn Hard Rubber	717069	
Fluorosilicone/polyester	Diaphragm		E I DuPont	Fairprene 44 002	Urine system
Gelatin/polyester/silver halide/proprietary dye	Film		Eastman Kodak	Panatomic X aerial film type 3000 estar thin base	Camera
Graphite/arochlor (chloropolyphenyl)	Lubricant		Armite Lab (Los Angeles)	LOX safe	Gas management assembly

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Latex	Foam	H S SV 710423 2	Toyad Corp	Updown no 1183	Gas management assembly
Latex/glass	Filter		Flanders Filter	F700	Feces container
Melamine/glass	Laminate	MIL-P-15037	General Electric	Textolite 11628	Insulated washer 47B115873, structure assembly
Napthenic hydrocarbon	Grease		Fiske Brothers	Lubriplate	Camera
Paraffinic hydrocarbon	Lubricant		American Oil Co (South Bend Lathe)	Ind Oil no 9 (CE 2017)	Urine system
Phenolic/cellulose	Structural plastic		General Electric	GE 1841	Camera controller
Phenolic/molybdenum disulfide	Lubricant		Electrofilm Co	Electrofilm 4306	Gas management assembly SV715680
Phenolic/polyamide/glass	Laminate		General Electric	Textolite 11545	Water dispenser 47E187857
Phenolic	Varnish		Sherwin Williams	Ajax V 61V3	Pellet feeder
Polyalkene/ polyvinylidene fluoride	Wire insulation	R2761	Ray Chem	44 Space Wire	Structure assembly
Polyalkene/ polyvinylidene fluoride	Wire insulation	R3986	Ray Chem	44A	Structure assembly
Polyamide	Nylon	R2729P10	Bendix, Powell & Avmet	P/A 10 263998 10 Iden no 102 90	Structure assembly
Polyamide/beeswax	Lacing tape	R2074	Hemmingway & Bartlett	GE Finish	Structure assembly

Generic identification	Classification/ product name	Spec /dwg no	Manufacturer	Manufacturer's identification	Component
Polyamide	Nylon	MIL P 77091B Type I, II	E I DuPont	Nylon	Gas management assembly
Polyamide	Nylon		E I DuPont	Nylon	Capsule relief valve, pellet feeder, water dispenser, urine system, gas management assembly
Polyamide	Nylon		E I DuPont	Zytel 101	Gas management assembly, camera controller
Polyamide	Lacing tape	R2074 P1	GudeBrod Brothers	18 White, 21	Recovery programmer, feces container, reentry vehicle inverter, gas management assembly
Polyamide	Resin		General Mills	Versamid 125	Biomedical tape recorder
Polycarbonate	Structural plastic		General Electric	Lexan	Water dispenser
Polycarbonate	Structural plastic	AMS 3628	Commercial Plastics	Lexan 101 111	Gas management assembly
Polycarbonate	Structural plastic	AMS 3628	Westlake Plastics	Lexan 101 111	Gas management assembly
Polyester	Tape		Bronnell Inc	Mylar tape A, no 9	Gas management assembly
Polyester	Dacron		Stern & Stern	No 15251	Gas management assembly
Polyester/acrylic	A1 mylar/P S adhesive		W B Brady	B 188	Water dispenser
Polyester	Mylar tape	R3879P1	3M	No 888	Biomedical tape recorder
Polyester	Dacron		Troy Mills	Troy style S4 19 070	Gas management assembly

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Polyester	Insulating varnish		General Electric	No 9522	Gas management assembly
Polyester	Adhesive	MIL-A 1200	Rohm & Haas	ParaplexP43	Gas management assembly SV715680
Polyester	Tape		E I DuPont	Mylar	Gas management assembly, wire harness
Polyethylene	Thermoplastic		E I DuPont	Corofon	Fiber optics
Polyethylene	Fitting		Crawford Fitting	P200 1, P601 A, P200 7 2	Urine system, water dispenser
Polyolefin	Tubing	MIL-23053/5	Rayclad Inc	Rayolin N F	Gas management assembly, wire harness
Polyolefin	Sleeving	R2479	Penna Fluorocarbon	Penn Tube V	Recovery programmer, urine system, camera controller, structure assembly
Polypropylene	Fitting		U S Plastics	640 10	Urine system
Polystyrene/ divinylbenzene sulfonate resin	Amberlyst resin	R6371P1	Rohm & Haas	Amberlyst 15	Trace gas assembly 47C139234
Polyurethane	Foamade	R6378P1	Scott	Scott Fiberfoam 10 ppI	Filters 47C142691P1
Polyurethane	Scottfoam		Scott	Foam G	Feces container
Polyurethane	Sealant	156A9863	Columbia Tech Corp	Humiseal	Programmer timer 47E187336, recovery programmer 47E182584

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Polyurethane	Potting compound	156A9877P1	Product Research	PR1538	Programmer timer 47E187336, board assembly 47C168450, urine collection assembly 47E189400, G switch 47C138864, recovery programmer 47E182584, multicoder 47C138100, structure assembly
Polyurethane	Foam	128A5532	Nopco Chemical	Foam F-403	Housing assembly 47C139233
Polyurethane	Foam		Emerson & Cuming	Ecco Foam FPH	SCO assembly 47C137254
Polyurethane	Foam		Emerson & Cuming	Ecco Foam FP 6	Biomedical tape recorder
Polyurethane	Foam		Nopco	BX 249N	Gas management assembly
Polyurethane	Foam, rigid		Nopco	Foam A 210	Gas management assembly
Polyurethane	Foam		Nopco	Foam F 506	Gas management assembly
Polyurethane	Foam		Nopco	Foam F 202	Feces container
Polyurethane	Coating		Magna Chemical & Coating Co	Laminar X 500	Structure assembly, gas management assembly SV 731700
Polyurethane	Potting compound		U S Mach	Bostik 7070	Gas management assembly
Polyvinylacetate/ acrylic	Marking ink		NaZ-Dar Co	GV 111 Black Glass Vinyl Ink	Gas management assembly
Polyvinylchloride	Coating		Alpha Wire Corp	PVC, Type F Sub formula GR C, Class 1 Category 1	Gas management assembly

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Polyvinylchloride	Tubing		Raychem	Thermofit Rayclad, PVC 3/8	Gas management assembly
Polyvinylchloride	Tubing	R6343	Norton Plastics (formerly U S Stoneware)	B 44 4X Tygon	Gas management assembly, structure assembly
Polyvinylchloride	Tape	R6358	3M	No 478 Plastic Film Tape	Structure assembly
Polyvinylchloride	Tubing		Alpha Wire	Alphlex 105/24	Gas management assembly
Polyvinylacetate/ tetrafluoroethylene	Sleeve wrapping		Hygro Dynamics		Gas management assembly
Polyvinylidene fluoride	Sealer	156A8979P2	Corrosion Reaction	BRC6 Vinyl Hyde	Recovery programmer, reentry vehicle power controller
Polyvinylidene fluoride	Overcoat	156A8979P5	Corrosion Reaction	BRC4 Vinyl Hyde	Recovery programmer, reentry vehicle power controller
Polyvinylidene fluoride	Film		Penn Salt	Kynar	Gas management assembly, wire harness
Polyvinyl fluoride	Tape		3M	Tedlar, Y 9057	Structure assembly
Silicone	Potting compound	165A4423P1	Dow Corning	XR 6 3700	Recovery Beacon 47D167098
Silicone	Adhesive	47A101720Tyl	Dow Corning	No 281	Cover and gasket 47C137337

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Silicone	Potting compound	165A4444P1	General Electric	RTV 615	Module 47D170865, module 47D170893, module 47D175055, module 47D170894, recovery programmer 47E182584, camera controller 47E188580
Silicone	Silicone rubber	AMS3304	Conn Hard	Corhlastic 700	Light assembly 47C138704, urine system
Silicone	Grease	156A9431D1 (MIL-S 8660B)	General Electric	SS4005	Reentry transmitter 47C137113
Silicone	Sealant	47A101905	Dow Corning	92 018	Reentry transmitter 47C137113
Silicone	Adhesive	R6387P1	Dow Corning	92 024	Urine system
Silicone	Silicone rubber		Dow Corning	DC 370	Urine system
Silicone	Silicone rubber		Dow Corning	DC 372	Urine system
Silicone	Coating		North American	Ladicote FRF FL	Gas management assembly
Silicone	Silicone rubber		Eckel Valve	SK1500 (M 15)	Gas management assembly
Silicone	Silicone adhesive	156A9852P1	General Electric	RTV102	Structure assembly, gas management assembly
Silicone/molybdenum disulfide	Lubricant	146A9332	Moly Kote Corp	M 77	Structure assembly
Silicone	Silicone rubber	AMS3196	Airex Rubber		Gas management assembly

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Silicone	Varnish	156A9420	Dow Corning	DC996	Telemetry transmitter 47C137113
Silicone	Adhesive	R6424	Emerson & Cuming	Eccoshield RVS	Camera controller
Silicone	Silicone rubber	1285469D2	General Electric	SE555	Structure assembly, scale 47B113617, gasket 47B113620, water dispenser 47E187857, urine system, feces container capsule relief valve 47C142321
Silicone	Silicone primer	128A5485P4	Dow Corning	A4094	Urine system, gas management assembly
Silicone	Silicone high vacuum grease	147A1803	Dow Corning	DC 11	Recovery beacon 47D167098, trace gas assembly 47C139234, gas management assembly
Silicone	Potting compound		Dow Corning	No 332	Commutator
Silicone	Silicone rubber		General Electric	SE 550	Capsule relief valve
Silicone	Adhesive		Borden Chemical	Mystik 7020	Pellet feeder
Silicone	Silicone rubber		General Electric	RTV 11	3G switch 681C385, gas management assembly
Silicone	Silicone rubber		General Electric	RTV 601	Gas management assembly
Silicone	Silicone primer		General Electric	SS 4004	Feces container, gas management assembly SV715620

Generic identification	Classification/ product name	Spec /dwg no	Manufacturer	Manufacturer's identification	Component
Silicone	Silicone grease		Dow Corning Co	DC55M	Structure assembly
Silicone	Silicone tape	146A9597	Frank Markel, Inc	Flextite T G L tape	Recovery programmer 47E186923, structure assembly
Silicone	Primer	128A5489P1	Dow Corning Co	A4004	Water dispenser 47E187857, feces container rack 47C138523, G2, Pad 47B113144P, structure assembly
Silicone	Grease	156A8952	Dow Corning Co	DC 5	Structure assembly
Silicate/ester	Coolant	47A101748	Monsanto	Coolanol 25	Environmental control
Silicone	Silicone rubber		General Electric	RTV60	Pellet feeder
Silicone	Silicone rubber		Dow Corning Co	RTV731	Gas management assembly
Silicone	Silicone rubber		General Electric	SE5211	Gas management assembly
Silicone	Conductive gasket	R3698P2	Chomerics	Choseal 1214	Recovery programmer 47E186923, gasket 47B114544, separator assembly 47B115244, camera controller 47E188580
Silicone	Silicone rubber castable adhesive	R6394P1	Dow Corning Co	DC93 072	Air plenum diffuser duct
Silicone	Silicone coating	165A4424P1	RS/GE	PD147(RTV511 + TiO_2)	Air plenum diffuser duct

Generic identification	Classification/ product name	Spec /dwg no	Manufacturer	Manufacturer's identification	Component
Silicone	Flexible duct	ZZ R 765A Class III, GR 50 GE Cpd SE555+181 Glass Cloth MIL-Y-1140	Haveg		Flexible duct 47C1434521
Silicone	Lubricant	128A5473	Dow Corning Co	DC7	Relief valve 47B113135
Silicone/acrylic	Paint		Bruder Co	C6B(black)	Reentry vehicle inverter
Silicone	Silicone rubber		General Electric	RTV602	Multicoder 47C138100
Silicone	Silicone rubber		General Electric	SS4044	3G switch 681C385
Silicone	Packing	MS9068	Parker Rubber	S604 7	Light assembly 47C178704
Silicone	Silicone rubber		General Electric	RTV511	Gas management assembly
Silicone	Packing	MIL-R-5847, C13 Gr 50	Precision Rubber	694 94 P 238	Gas management assembly
Silicone	Packing	MIL R 5847, C13 Gr 50	Nichols Eng Co	694 90 L 239	Gas management assembly
Silicone	Silicone rubber		Dow Corning Co	RTV891	Gas management assembly
Silicone	Silicone rubber	AMS3332	Airex	Airex 15 30	Gas management assembly
Silicone	Silicone rubber		Dow Corning Co	DC6526	Gas management assembly
Silicone	Varnish		General Electric	No 996	Reentry transmitter
Silicone	Silicone rubber		Dow Corning Co	Silastic S 2000	Urine system
Silicone	Silicone adhesive		Dow Corning Co	Silastic 373	Urine system

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Silicone	Alum/silicone rubber	146A9333P2	Metex	Alum/silicone rubber	Reentry vehicle inverter
Silicone	Silicone rubber		General Electric	GE550	Relief valve 47C142221
Silicone	Silicone rubber		General Electric	GE555	Relief valve 47C142221, pellet feeder
Silicone	RTV silicone rubber	156A9874P1	General Electric	RTV 560	Couch assembly 47R197322, structure assembly
Silicone	Silicone rubber		General Electric	GE4404	Urine system, structure assembly
Silicone	Silicone rubber tubing	R3991P2	Dow Corning Co	Silastic 372	Structure assembly 47E190825G3
Silicone/glass	Fiber glass reinforced silicone rubber	MIL-H 8796 Type 1, Class I MIL-R-5847 Class 11B, Gr 50 (47C142217)	Stockwell Rubber	FT 9862 1 Type L-9 Flex Flyte Flexible Hose	Structure assembly
Silicone	Silicone rubber sponge	MIL-R 6130 Type 11, Gr C Firm or Medium	Conn Hard Rubber	Cohrlastic R-10470	Structure assembly, feces container
Silicone	Silicone adhesive	128A5502	Dow Corning Co	A4000	Regulator assembly 47C137672, water dispenser 47E187857, urine system, feces container, reentry vehicle inverter 47E188594, rack 47C138523, structure assembly

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Silicone	RTV silicone rubber	156A9852	General Electric Co	RTV103	Structure assembly
Silicone	RTV silicone rubber	156A9852	General Electric Co	RTV106	Structure assembly
Silicone	RTV silicone rubber	156A9852	General Electric Co	RTV108	Urine system, SCO assembly, 47C137254, structure assembly, gas management assembly, SV 715680
Silicone	RTV silicone rubber	156A9852	General Electric Co	RTV109	Structure assembly
Rubber,natural	Natural latex tubing	R6317P2	Rubber Latex Products	RLP tubing	Structure assembly
Styrene/butadiene	Synthetic rubber	MIL-R 3065 RS515, Type R, Cl R S	Associated Gasket		Gas management assembly
Tetra ethylene glycol diacrylate	Sealant	MIL-S 22473	American Sealants	Loctite A	Gas management assembly
Tetra ethylene glycol diacrylate	Sealant	MIL S 22473	American Sealants	Loctite A101	Gas management assembly
Tetra ethylene glycol diacrylate	Sealant	MIL S 22473	American Sealants	Loctite C	Structure assembly, timer programmer, recovery beacon, feedline disconnect, couch assembly
Tetra ethylene glycol diacrylate	Sealant	MIL-S 22473	American Sealants	Loctite E	Biomedical tape recorder
Tetra ethylene glycol diacrylate	Sealant	MIL S 22473	American Sealants	Loctite H	Urine collection assembly, structure assembly

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Tetra ethylene glycol diacrylate	Sealant	MK S 22473	American Sealants	Loctite HV	Urine collection assembly
Tetrafluoroethylene	Teflon tape	R3777P2	Conn Hard Rubber	Temper R Tape TH	Pellet feeder, structure assembly
Tetrafluoroethylene	Fluoro plastic	R3627P1	E I DuPont	Teflon	Water dispenser assembly, urine system
Tetrafluoroethylene	Fluoro plastic	R2660 P50005	Penn Fluorocarbon	TFE-4 Thin wall	Recovery programmer
Tetrafluoroethylene	Fluoroplastic	MIL-W5838	E I DuPont	Teflon wire insulation	Gas management assembly
Tetrafluoroethylene/ fluorinated ethylene propylene	Twinax cable		Micro Dot	202 3924 Micro Dot	Gas management assembly
Tetrafluoroethylene	Bacteria filter		Aircraft Porous Media	AC2269-2	Feces container
Tetrafluoroethylene	Fluoroplastic	R2170P2	Penn Fluorocarbon	Penn tube 1-22 Black	Recovery programmer
Tetrafluoroethylene	Teflon felt	HSSV707860 35	American Felt		Gas management assembly
Tetrafluoroethylene	Teflon fiber		American Felt	TE1029	Gas management assembly
Tetrafluoroethylene	Wire insulation	MIL W 16878	Philadelphia Ins Wire	100 021	Structure assembly, gas management assembly
Tetrafluoroethylene	Wire insulation	MIL-W 16878	Belden Co	Lead wire insulation	Pellet feeder
Vinyl	Adhesive	R6310P1	Emerson & Cuming	EccoShield VCA	Timer programmer, recovery programmer, reentry vehicle inverter, camera controller

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Vinyl	Conductive plastic gasket	R6309P1	Emerson & Cuming	EccoShield SV	Separator assembly cushion, recovery programmer, reentry transmitter, camera controller
Vinyl nitrile	Plastic foam	MIL-P-15280 Type II	Armstrong Cork	Armaflex 22	Structure assembly
Polycarbonate	Plastic case	FDA grade	Unknown	-	Dosimeter (provided by NASA)
Polyethylene	Plastic sheet	N/A	N/A	N/A	Dosimeter (provided by NASA)
Nylon	Sheet	N/A	N/A	N/A	Dosimeter (provided by NASA)
Epoxy	Adhesive foam	N/A	Furane Products	Epocast 2 D	Dosimeter (provided by NASA)

In addition to the materials used in the fabrication of the structure and components, various solvents and other shop aids were used during the manufacturing cycles They are

Trichloroethylene	Toluene
Methyl ethyl ketone	Denatured alcohol
Acetone	Ethyl alcohol
Water	Safety solvent per MIL-S 1871
Water with 1 percent 7X detergent	
Freon 113	Freon PCA

APPENDIX B

NONMETALLIC MATERIALS FOR ELECTRONIC EXPERIMENT AND ELECTROMECHANICAL EQUIPMENT

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification
Polyester, adhesive backing, rubber resin	Tape	N/A	Minnesota Mining & Mfg	3M Tape No 75
Polyamide, adhesive backing, silicone	Tape	N/A	Minnesota Mining & Mfg	3M Tape No 92
Epoxy paint	Paint	47A101931	Finch Paint & Chemical Co	CAT-A LAC, Code 42
Polyurethane	Conformal coating	N/A	Products Research & Chemical Co	PRC 1535
Epoxy	Polyamid adhesive	N/A	Emerson Cummings	EC-1614
Epoxy foam	Epoxy foam	N/A	Ablestic Adhesive Co	Ablefoam No 1
Epoxy	Filled epoxy potting compound	N/A	Emerson Cummings	Stycast 1090 (Catalyst No 11)
Silicone	Silicone rubber	N/A	General Electric Co	RTV 60 (Thermaline 12 Catalyst)
Silicone	Primer	N/A	General Electric Co	SS 4004
Silicone	Bonding silicone, rubber adhesive, sealant	N/A	Dow Corning	DC92018
Oil	Whale oil	N/A	Hamilton Watch Co	PML 79
Polyurethane	Conformal coating	N/A	Columbia Technical Corp	Humiseal 1A-27
Polyurethane	Conformal coating	N/A	Products Technique, Inc	PT 750

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification
Epoxy	Epoxy/glass laminate	N/A	Northrop Electronics	FR-5
Epoxy	Epoxy/glass laminate	N/A	Northrop Electronics	G-11
Polyurethane	Foam potting	N/A	Northrop/L A D Sales	775-6278
Silicone	Silicone grease	N/A	Dow Corning	DC-4
		Solvent used during manufacture		
Unknown	Cleaning solvent	N/A	John B Moore Corp	M 50

APPENDIX C

NONMETALLIC MATERIALS FOR MONKEY COUCH AND EQUIPMENT MOUNTED THEREON
(Except heavy-particle dosimeter)

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Polyamide	Interwoven nylon and cotton	Mil C-4487	Wright-Patterson AFB	Mil C-4487	Monkey restraint and garment
Polyamide	Velcro, nylon	N/A	N/A	Velcro	Monkey restraint and garment
Polyamide	Nylon net	N/A	N/A	Nylon	Monkey restraint and garment
Polyamide	Nylon lacing cord	N/A	N/A	Nylon	Monkey restraint and garment
Polyurethane	Foam (soft)	N/A	N/A	Polyurethane foam	Pillow
Vinyl	Naugahyde	N/A	N/A	Naugahyde	Reinforcement
Tetrafluoroethylene	Teflon coating	N/A	E I DuPont	Teflon	Feces collector coating
Silicone	Silastic tubing	N/A	Dow Corning	Silastic No 372	Urine catheter
Fluoro carbon	Viton	N/A	E I DuPont	Viton B	Urine catheter
Chlorofluorocarbon	Kel-F coating	N/A	Minnesota Mining & Mfg	Kel-F	Urine catheter
Polyvinyl chloride	Tubing	N/A	Norton Plastics	N/A	Heparin system
Urethane	Coating	N/A	CRC Chemicals	N/A	Pressure transducers
Dimethyl polysiloxane SiO_2	Silicone grease	N/A	Dow Corning	DC 4	Signal conditioner hooking seal
Epoxy	Potting compound	N/A	Emerson & Cumming	Stycast 256-1-40	Pump housing

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Polyester	Mylar	N/A	E I DuPont	Mylar	Pump
Epoxy paint	Epoxy polymide paint	47A101931	Finch Paint & Chemical	Cat-A Lac	Signal conditioner, couch frame
Epoxy	Potting compound	N/A	Emerson & Cumming	Stycast 1090 (Catalyst No 11)	Signal conditioner (same as appendix B)
Polyurethane	Conformal coating	N/A	Columbia Tech Corp	Humiseal 1A-27	Signal conditioner (same as appendix B)
Epoxy	Epoxy foam	N/A	Ablestick Adhesive Co	Able foam No 1	Signal conditioner (same as appendix B)
		Cleaning compounds used in manufacture			
Unknown	Cleaning solvent	N/A	John B Moore Co	M 50	Signal conditioner
Unknown	Cleaning solvent	N/A	CRC Chemical	Lectra Clean	Pressure transducers

APPENDIX D

NONMETALLIC MATERIALS PECULIAR TO THE ELECTRICALLY ACTUATED (ELECTRIC) FOOD PELLET DISPENSER

These materials are in addition to those listed in appendix G

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Application
Silicone	Silicone oil	N/A	British, available from EFDYN, Co Chicago	Unknown	Dashpot
Organic	Oil	N/A	Shell Oil Co	Beacon No 325	Motor lubricant
Organic	Oil	N/A	Shell Oil Co	Aeroshell No 7	Gear lubricant
Phenolic	Varnish, insulation	N/A	Sherwin-Williams Paint Co	Ajax V 61V3	Winding insulation
Tetrafluoroethylene	Teflon insulation	N/A	E I DuPont	Teflon ML	Magnet wire insulation
Tetrafluoroethylene	Teflon insulation	M-W-16878	Belden Co	N/A	Lead wire insulation
Polyester	Mylar film	N/A	DuPont	Mylar	Insulation
Glass, adhesive backed, unknown adhesive	Glass tape	N/A	Borden Chemical Co	Mystik No 7020	Tape
Organic	Screw locking varnish	N/A	General Electric Co	Glyptal	Screw locking
Neoprene	Neoprene rubber	N/A	Stockwell Rubber Co	No 7465	Reel brake
Epoxy	Epoxy adhesive	147A1299	Emerson-Cumming	EC 1357	Reel brake adhesive

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APPENDIX E

NONMETALLIC MATERIALS FOR ORIGINAL-CONFIGURATION HEAVY-PARTICLE DOSIMETER

Generic identification	Classification/ product name	Spec/dwg no	Manufacturer	Manufacturer's identification	Use
Polyester, adhesive backing	Tape	EM/640 BA	Minnesota Mining & Mfg	Scotch No 56	Tape edges of pack
Inorganic	Emulsion	N/A	N/A	Silver bromide in gel	Nuclear emulsion, sealed between Lexan sheets with 3145 cement
Cellulose triacetate	Plastic sheet	N/A	German Import	Triofol	Heavy particle record
Silicone	Silicone cement	N/A	Dow Corning	DC 3145	Glue Lexan sheets together
Polycarbonate	Sheet Lexan	N/A	N/A	Lexan	Nuclear particle record

APPENDIX F

NONMETALLIC MATERIALS FOR FINAL-CONFIGURATION HEAVY-PARTICLE DOSIMETER

The final dosimeter configuration included the materials listed in appendix E, but all were enclosed within an anodized, aluminum case which was sealed The only nonmetallic material exposed to the cabin atmosphere was the following

Generic identification	Classification	Spec/dwg no	Manufacturer	Manufacturer's identification	Use
Ethylene propylene terpolymer	Soft propylene	N/A	E I DuPont	Nordell	Case seal

APPENDIX G

NONMETALLIC MATERIALS FOR MECHANICALLY ACTIVATED (MECHANICAL) FOOD PELLET DISPENSER

Generic identification	Classification	Spec/dwg no	Manufacturer	Manufacturer's identification	Component
Acetal resin	Delrin	N/A	E I DuPont	Delrin	Ratchet
Tetrafluoroethylene	Teflon tape	N/A	Unknown	Teflon	Pellet reels
Polyamide	Nylon	N/A	Unknown	Nylon	Pellet reels
Unknown	Unknown	N/A	Fish Paper	Unknown	Switch insulator
Epoxy	Epoxy adhesive	N/A	Minnesota Mining & Mfg	EC 711	Adhesive
Organic	Screw locking varnish	N/A	General Electric	Glyptal	Screwlock
Epoxy	Epoxy polyamide paint	47A101931	Finch Paint & Chemical	Cat-A-Lac white paint	Paint
Polyurethane	Polyurethane foam	N/A	Unknown		Foam
Rubber-based cement	Adhesive	N/A	National Starch & Chemical Co	36-6038 & 36-6040	Adhere pellet to teflon tape
Silicone	Silicone rubber	N/A	General Electric	SE-555	Pellet protection
Organic	Food pellet	47A102802	Pillsbury	PC920	No harmful content by test
Shellac	Edible arsenic-free shellac	N/A	Montrose Chemical Co	Mantralac	Pellet coating

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TABLE 1 – COMPARISON OF SAFE LIMITES TO ANALYTICAL SENSITIVITIES (BACKGROUND LEVELS) FOR RESTRICTED COMPOUNDS FOR GRAB SAMPLES

[Values are in ppm unless noted]

Restricted compound	Safe limit	Maximum threshold of quantification (background) detectability of grab sample technique
Acetone	300	1 0
Alcohol, n butyl	10	0 1
Alcohol, ethyl	100	1 0
Alcohol, isopropyl	50	1 0
Alcohol, methyl	10	0 1
Total hydrocarbons	70 mg/m^3	4 0 mg/m^3 as hexane
Ammonia	25	5 0
Benzene	1 0	1 0
2 butanone	20	~5 0
Carbon monoxide	25	10 0
Cis dichloroethylene	0 1	0 02
Chloroform	5 0	0 01
Dichloroacetylene	0 01	0 01
Dichloromethane	25	0 01
Dioxane	10	0 3
Ethyl acetate	40	0 001
Ethylene glycol	20	~1 0
Ethylene oxide	5 0	2 0
Fluorophosgene	0 01	0 01
Formaldehyde	0 1	0 1*
Freon 11	5 0	0 01
Freon 12	200	0 01
Freon 113	150	0 01
Freon 114	200	0 01
Hydrogen chloride	1 0	0 1
Hydrogen fluoride	0 1	0 1
Hydrogen sulfide	20	1 0
2 methyl butanone	20	~5 0
Mercury	0 01 mg/m^3	0 025 mg/m^3
Monochloroacetylene	0 01	0 01
Ozone	0 02	~0 1
Phosgene	0 05	0 01
Sulfur dioxide	1 0	None established
Trans dichloroethylene	0 1	0 02
1,1,1 trichloroethane	5 0	0 01
Trichloroethylene	0 1	0 02
Vinylidene chloride	0 1	0 02
Total chlorides	25 mg/m^3	~0 01 mg/m^3
Halogenated hydrocarbons	None established	5 0

*Total aldehydes expressed as formaldehyde

TABLE 2 – DESCRIPTION OF TESTS

Test designation	Test type	Description	Chamber or cabin volume, liters	Equipment operating	Monkey	Monkey couch	Heavy particle dosimeter	Pellet (food) dispenser	O_2 partial pressure sensor*	LiOH and charcoal loop	Trace gas removal assembly	N_2 to cabin or chamber	O_2 to cabin or chamber
A1	Spacecraft operating	Prototype cabin	183	Yes	No 479 and No 453	Yes	Yes No 479 no No 453	Mechanical	Yes	Open	Open	External bottle	External bottle
A2	Spacecraft, operating	Flight cabin	183	Yes	No 478	Yes	No	Mechanical	Yes	Open (nonflight)	Open (nonflight)	Internal tank	External bottle
A3	Spacecraft static	Flight cabin	188 5	No	None	None	No	None	None	Closed (flight)	None	No	No
A4	Spacecraft operating	Flight cabin	188 5	Yes	None	None	No	Mechanical	Yes	Closed (flight)	Closed (flight)	No	No
A5	Spacecraft, static, some operation	Flight cabin	188 5	Short periods	None	Yes	No	Mechanical	No	Closed (flight)	Closed (flight)	No	With He inadvertent from inter nal tank
A6	Spacecraft operating	Flight cabin	188 5	Yes	None	Yes	No	Electrical (flight)	Yes (flight)	Closed (flight)	Closed (flight)	Internal tank	Internal tank
A7	Spacecraft operating	Flight cabin prelaunch	183	Yes	No 470	Yes	Yes	Electrical	Yes	Open	Open	Internal tank	Internal tank
A8	Spacecraft operating	Flight cabin recovery	183	Partial during recovery	No 470	Yes	Yes	Electrical	Yes	Open	Open	Internal tank cut off at separation	Internal tank
B1	Component operating	Experiment Electronic and electro mechanical equipment	~156	Yes	N/A	N/A	N/A	N/A	N/A	N/A	N/A	No	No
B2	Component operating	Monkey couch with electronic support equipment, without nylon restraint garment	~156	Yes	None	Yes less restraint	N/A	N/A	N/A	N/A	N/A	No	No
B3	Component passive	Heavy particle dosimeter, first configuration and	3 8	N/A	N/A	N/A	Yes	N/A	N/A	N/A	N/A	No	No
B3a	Parts	(B3a) parts thereof Test specimen had been used in test A1	1 9										

*This component contains teflon as only nonmetallic nonglass material

TABLE 2 – DESCRIPTION OF TESTS – Continued

Test designation	Test type	Description	Chamber or cabin volume liters	Equipment operating	Monkey	Monkey couch	Heavy particle dosimeter	Pellet (food) dispenser	O_2 partial pressure sensor*	LiOH and charcoal loop	Trace gas removal assembly	N_2 to cabin or chamber	O_2 to cabin or chamber
B4	Component passive	Heavy particle dosimeter final (flight) configuration flight unit	~156	N/A	N/A	N/A	Yes, flight	N/A	N/A	N/A	N/A	No	No
B5	Component operating	Monkey food dispenser flight unit (electric)	~156	Yes	N/A	N/A	N/A	Electrical	N/A	N/A	N/A	No	No
B6	Component, operating	Same as B5	~156	Yes	N/A	N/A	N/A	Electrical	N/A	N/A	N/A	No	No
C1	Monkey with couch	Monkey with supporting equipment simulated operations	~183	Yes	No 509	Yes	No	Food only	N/A	N/A	N/A	Bottled air	Bottled air
C2	Monkey with couch	Monkey with supporting equipment complete operations	~183	Yes	No 504	Yes	No	Food only	N/A	N/A	N/A	Bottled air	Bottled air
D1	Component nonoperating	Flight LiOH and charcoal can assemblies	N/A	No	N/A	N/A	N/A	N/A	N/A	Open, flight	N/A	N/A	N/A
D2	Component nonoperating	Same as D1	N/A	No	N/A	N/A	N/A	N/A	N/A	Open flight	N/A	N/A	N/A
D3	Component nonoperating	Spare LiOH and charcoal can assemblies can shells had been used in test A1 before reloading	N/A	No	N/A	N/A	N/A	N/A	N/A	Open	N/A	N/A	N/A
D4	Component passive	Flight trace gas removal assembly	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Open flight	N/A	N/A
E1	Charcoal flow	Flight type charcoal in lab setup	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
E2	Charcoal flow	Charcoal used in test A1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F1	LiOH analysis	Analysis only of LiOH used during test A1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

*This component contains teflon as only nonmetallic nonglass material

TABLE 2 – DESCRIPTION OF TESTS – Continued

Test designation	Test type	Description	Chamber or cabin volume liters	Equipment operating	Monkey	Monkey couch	Heavy particle dosimeter	Pellet (food) dispenser	O_2 partial pressure sensor*	LiOH and charcoal loop	Trace gas removal assembly	N_2 to cabin or chamber	O_2 to cabin or chamber
F2	LiOH analysis	Analysis only of unused LiOH	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F3	LiOH analysis	Analysis only of flight LiOH	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F4	Charcoal analysis	Analysis only of charcoal used during test A1	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F5	Charcoal analysis	Analysis only of charcoal used during test A2	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F6	Charcoal analysis	Analysis only of unused charcoal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F7	Charcoal analysis	Analysis only of flight charcoal	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
F8	Amberlyst analysis	Analysis only of flight amberlyst	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
G	Supply gas	Analyses of gases supplied to spacecraft and to test chambers	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Sample	Sample
H	Ambient atmospheres	Ambient atmospheres in monkey transporter, monkey laboratory launch pad greenhouse' and manufacturing plant	Very large	Yes	No	No	N/A	No	N/A	No	No	Air conditioning	Air conditioning
J1	Special	Quick disconnect sample fitting	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J2	Material	White vinyl tape	5 cc	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
J3	Special	Recovery sample-bottle container	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

*This component contains teflon as only nonmetallic nonglass material

TABLE 2 – DESCRIPTION OF TESTS – Continued

Test designation	Chamber or cabin flushed before closure	Test atmosphere	Nonmetallic materials listed in appendixes	Longest sample period hr	Sample methods	Number of analysts	Results reported in	Test limitations	Description and remarks
A1	No	Cabin air	A B C E	375	Grab special grab H_2S	2	Table 3	Only tested for CO NH_3 H_2S CH_2O and ethylene oxide Chlorinated hydrocarbons were also tested for after 180 hr of second test period (after insertion of monkey no 453)	Charcoal and LiOH were analyzed after test, see tests F1 and F4 See note (1)
A2	No	Cabin air	A B C	110 5	Grab, special grab H_2S	2	Table 4	As above	See note (2) Charcoal analyzed after test see test F6
A3	No	Air	A B, less G	120	Grab	2	Table 4	No mixing of atmosphere equipment non operating Only chlorinated hydrocarbons and some aromatics were tested for Experiment electronics and urine system not installed No background sample taken	
A4	Yes bottled air	Cabin air	A B	24	Grab, Hg	6	Table 4	No test for HCl HF CO H_2S SO_2, O_3, or total chlorides Some components not flight units No gas supplied to cabin	All systems were operated to a simulated flight profile but LiOH, charcoal and trace gas removal assemblies were closed off Capsule heaters were energized for 1/2 hr prior to taking 12 hr samples
A5	No	Air	A B C	601	Grab	2	Table 4	Partial analysis only No mixing of atmosphere prior to sampling Results of sample taken at 601 hr are questionable	See note (3)
A6	No	Cabin air	A B C D F	45	Grab	5	Table 4	No test for HCl HF SO_2 O_3 or Hg	See note (4)
A7	No	Cabin air	A B C, D F	0 75	Grab special grab H_2S	5	Table 4	No test for HCl HF SO_2, O_3 or Hg	Prelaunch baseline 12 hr prior to launch See note (5)
A8	N/A	Cabin air	A B C D F	249 2	Grab, special grab H_2S	4	Table 4	No test for HCl HF SO_2 O_3 or Hg Sample bottles had been evacuated for as long as 3 wk before use Quick disconnects were contaminated with Freon 113 and other compounds	LiOH and charcoal analyses covered by tests F3 and F7 Amberlyst analyzed for NH_3 content, see test F8 See note (5)
B1	Yes, bottled air	Air	B	24	Grab	2	Table 5	Chamber atmosphere not mixed fully before sample No test for NH_3 HCl, HF H_2S Hg O_3 SO_2 aldehydes or total chlorides	Tested in KSC bell jar
B2	Yes, bottled air	Air	C	24	Grab	2	Table 5	Same as B1, but *no* mixing of chamber atmosphere	Tested in KSC bell jar (same as B1)

TABLE 2 – DESCRIPTION OF TESTS – Continued

Test designation	Chamber or cabin flushed before closure	Test atmosphere	Nonmetallic materials listed in appendixes	Longest sample period, hr	Sample methods	Number of analysts	Results reported in	Test limitations	Description and remarks
B3 B3a	No	*Low pressure air*	*E*	*240*	*Special grab*	*1*	*Table 5*	*Chamber volume not representative of cabin* Atmosphere not representative due to low pressure Atmosphere not mixed prior to sampling Analyzed only for certain compounds – see table 5	*Passive component See note (6)*
B4	Yes bottled air	Air	F	36	Grab	2	Table 5	No test for NH_3 HCl HF Hg O_3 H_2S SO_2 aldehydes or total chlorides	Tested in KSC bell jar (same as B1) See note (7)
B5	Yes bottled air	Air	D G	24	Grab	2	Table 5	Component not outgassed before test No test for NH_3 HCl, HF Hg O_3 SO_2 H_2S, aldehydes or total chlorides	Contaminant levels high required retest see test B6 Tested in KSC bell jar Food pellets dispensed exposed in bell jar for last 4 hr of test
B6	Yes, bottled air	Air	D G	24	Grab	2	Table 5	No test for NH_3 HCl HF H_2S Hg, O_3 SO_2 aldehydes, or total chlorides	Repeat of test B5 2 days later Food pellets dispensed exposed for 24 hr Test B5 served to outgas unit, test B6 contaminant levels very low Tested in KSC bell jar (same as test B1)
C1	Yes, bottled air	Air	C	120	Grab CRYO HCl HF	4	Table 6	Monkey exposed to simulated operations only Air inlet to chamber exceeded sample flow to keep CO_2 level down therefore only 6 4% of outlet was sampled Air supply tanks were changed so no true baseline was established No test for NH_3 Hg SO_2, H_2S aldehydes or total chlorides Urine system leaked	See figure 3 for test setup See note (8)
C2	Yes bottled air	Air	C	120	Grab CRYO, NH_3, HCl HF	3	Table 6	Same as test C1, except monkey was exposed to complete operations atmosphere was sampled for NH_3 and urine system did not leak Feces collector leaked	See figure 3 for test setup See note (8)
D1	Test specimen not flushed	N_2	Included in A	3	LN_2 CRYO	2	Table 7	Cans not heated Thus does not constitute a test of charcoal No test for HCl, HF, SO_2 H_2S NH_3 O_3 Hg CO aldehydes or total chlorides No baseline was established for gas flowing into assemblies due to cryogenic trapping upstream	Assemblies in place in spacecraft N_2 gas flowed through assemblies to LN_2 CRYO trap for 3 hr at 100 cc/min N_2 gas flowed through dry ice trap upstream of assemblies Assemblies were filled with N_2 before test See figure 2
D2	Not flushed	N_2	Included in A	3	LN_2 CRYO grab	2	Table 7	Same as test D1	Repeat of test D1, 30 hr later Much lower contaminant concentrations were found See figure 2 and text

TABLE 2 – DESCRIPTION OF TESTS – Continued

Test designation	Chamber or cabin flushed before closure	Test atmosphere	Nonmetallic materials listed in appendixes	Longest sample period, hr	Sample methods	Number of analysts	Results reported in	Test limitations	Description and remarks
D3	Flushed, N_2	N_2	Included in A	3	LN_2 CRYO	1	Table 7	This does not constitute a test of charcoal No test for HCl HF SO_2 H_2S NH_3, O_3 Hg CO, aldehydes, or total chlorides Assemblies were heated but only to 27° to 32° C	See figure 2 See note (9)
D4	Not flushed	N_2	Included in A	3	LN_2 CRYO	1	Table 7	No test for HCl HF SO_2 H_2S NH_3, O_3 Hg CO aldehydes, or total chlorides No baseline was established for gas flowing through assemblies due to cryogenic trapping upstream	N_2 gas flowed through assembly to LN_2 CRYO trap for 3 hr at 100 cc/min N_2 gas flowed through dry ice trap upstream of assembly See figure 4
E1	Not flushed	See note (10)	Carbon	117 5	See note (10)	1	See note (10)	Met objectives but not run to saturation	See figure 5 See note (10)
E2	Not flushed	See note (10)	Carbon	41 5	See note (10)	1	See note (10)	Met objectives but not run to saturation	See figure 5 See note (10)
F1	N/A	N/A	N/A	N/A	N/A	2	Table 8	No baseline sample	See table 8 for description of analysis
F2	N/A	N/A	N/A	N/A	N/A	2	Table 8		LiOH from same run as flight LiOH See table 8
F3	N/A	N/A	N/A	N/A	N/A	1	Table 8	Analyzed only for chloride content	Post flight analysis, test F2 is baseline
F4	N/A	N/A	N/A	N/A	N/A	3	Table 8	No baseline – unused sample from this lot was not tested Samples tested may not be representative of the total charcoal No tests for some compounds such as H_2S SO_2	Charcoal was desorbed (see text) and the effluent was cryogenically trapped for analysis See note (11)
F5	N/A	N/A	N/A	N/A	N/A	1	Table 9	See test F4	Same procedure as for test F4 See note (11)
F6	N/A	N/A	N/A	N/A	N/A	3	Table 9	No tests for some compounds such as H_2S SO_2	Charcoal from same run as flight charcoal Procedure same as test F4
F7	N/A	N/A	N/A	N/A	N/A	1	Table 9	Sample tested may not be representative of total charcoal No tests for some compounds such as H_2S SO_2	Post flight analysis Test F6 is baseline Procedure same as test F4 See note (11)
F8	N/A	N/A	N/A	N/A	N/A	1	See note (12)	Analyzed for NH_3 content only	Amberlyst resin from trace gas removal assembly, post flight See note (12)
G	N/A	N/A	N/A	N/A	Grab LN_2 CRYO	2	See note (13)	-	See note (13)

TABLE 2 – DESCRIPTION OF TESTS – Concluded

Test designation	Chamber or cabin flushed before closure	Test atmosphere	Nonmetallic materials listed in appendixes	Longest sample period, hr	Sample methods	Number of analysts	Results reported in	Test limitations	Description and remarks
H	No	Air	Not listed	N/A	Grab	3	See note (14)	Sampling methods used are not adequate for definitive analysis of atmosphere content except for monkey transporter Test therefore only confirms absence of serious contamination	See note (14)
J1	N/A	Air	N/A	N/A	Grab	1	See note (15)	Fitting had been stored for some time prior to test Limited number of compounds were tested for	See note (15)
J2	N/A	N/A	See note (16)	N/A	Special see note (16)	1	See note (16)	Purposely nonrepresentative of spacecraft environment	See note (16)
J3	No	Ambient air	N/A *	N/A	Grab	1	Table 10	Test run only as a check of potential contaminants No baseline sample of room atmosphere	Grab sample taken from inside recovery sample-bottle carrying/storage case at ambient conditions

NOTES

1 Test A1 Actually consisted of three test periods First period ended after 208 hr when sick monkey (479) was removed Second period began with insertion of monkey 453 and lasted 375 hr until a urine transport problem required opening cabin for 2 hr without removing animal Third period began with closure after fixing problem and lasted 53 hr until a pump failure caused termination

A complete description of physiological condition of animals is outside scope of this report, only pertinent observations are provided During first 7 days of first period, monkey 479 showed gradual decrease in heart and respiration rates On eight day, pronounced heart rate decrease was noted, breathing became very shallow and rapid Heart and breathing arythmia was observed Animal was comatose upon removal from cabin, and unable to close mouth around water dispenser nipple Intravenous fluid caused marked improvement within hours, but he became nauseated upon attempting to eat Evidence of vomitus was found in cabin Condition remained about same until expiration 7 days after removal Pathological examination showed some lung hemorrhage and fluid, but no kidney damage

Monkey 453 also showed decreasing heart and breathing rates after insertion, but after the eighth day of his occupancy, heart rate increased slightly and thereafter remained constant All other observed physiological indications were within expected limits Monkey was in satisfactory condition upon removal after 18 days

Urine system in cabin had been sterilized with 8 percent formaldehyde in ethanol and flushed until flush water contained no measurable formaldehyde, 48 hr before insertion of monkey 479 Procedure was not repeated prior to insertion of 453

2 Test A2 This was first ground test of flight spacecraft atmosphere, and only ground test of flight cabin with LiOH/charcoal and trace-gas removal assemblies open to flow Monkey was in closed spacecraft 5 days total, no physiological changes were noted that could be attributable to toxic gas

Urine system sterilization/flush was performed 48 hr prior to insertion of monkey

3 Test A5 Flight cabin, with some components removed, was kept closed for about 25 days to prevent external contamination, testing was done during this period During last 66 hr of this test, a leaking valve allowed gas from oxygen tank to pressurize cabin to approximately 1551 mm Hg Excessive pressure resulted in violent separation of fore and aft sections of cabin as it was unlocked in preparation for opening Samples taken just prior to separation incident (at 601 hr after closure) were used to identify source of excess pressure, trace gas analyses were performed after the samples were somewhat depleted, therefore, concentrations reported for 601 hr sample in table 4 have questionable validity

4 Test A6 The violent opening of cabin at end of test A5 (note 3) damaged some components, requiring their replacement Replacement components were "outgassed" by warming them in a vacuum chamber for 24 to 36 hr After most of new components had been installed in the cabin, this test, A6, was conducted on launch pad as part of a complete simulation of prelaunch activities A dummy monkey (largely silicone rubber) was used in the prelaunch simulation, but was removed from the cabin before closure (couch remained in cabin) For this test, gases were supplied from onboard tanks but LiOH/charcoal and trace gas removal assemblies were sealed

5 Tests A7-A8 Test A7 represents samples taken just after cabin was closed for launch and are therefore baseline for test A8, for which samples were taken after recovery from orbit and before cabin was opened Unscheduled early end of mission took place before planned cleaning and reevacuation of recovery sample bottles (test A8) could be effected Some bottles had been cleaned 3 weeks prior to use and none had been cleaned less than 13 days before use Proper procedure would have required cleaning no more than 24 hours (preferably 8 hr) before use Quick disconnects had been cleaned with Freon 113 but not vacuum outgassed afterward Sample bottles were stored before use in styrofoam filled containers (see "Discussion")

Until about 100 days before launch, open cabin had been exposed to manufacturing and test facility environments At launch site, cabin was exposed to semiclean room environment, with most solvents prohibited, until about 56 days before launch Cabin was then closed for 27 days, including 25 days of test A5 During last 29 days before launch, cabin interior was exposed to ambient environment in enclosed "greenhouse" on launch pad Greenhouse air-conditioning intake was near ground level, therefore, automobile exhaust gases, insecticide aerosols and volatile fluid spills around launch vehicle first stage could have entered greenhouse NASA/KSC Unmanned Launch Operations Directorate and launch vehicle contractors cooperated to control environment around entire launch pad to prevent contamination

Telemetry from spacecraft during orbital flight showed that partial pressure of oxygen was maintained at 146±6 mm Hg and that cabin total pressure was steady at 745±17 mm Hg It is believed that no N_2 was supplied to cabin during flight O_2 from the reentry/recovery tank was supplied for less than 4 hr Partial pressure of CO_2 varied between 1 1 and 4 3 mm Hg for first 8 days, then decreased during last 24 hr before recovery to below 1 mm Hg About 17 hr before recovery the diverter valve (fig 1) was operated so that both LiOH cans were in series flow, but changes in CO_2 level could not be correlated to this event

Leak test just before launch left about 1/2 percent of helium in cabin Batteries within cabin leaked hydrogen, resulting in recovery level of about 1/4 percent Analysis showed other constituents normally found in air, such as argon, at normal air levels at recovery

Urine system had been sterilized and flushed 48 hr before insertion of monkey (see note 2), a test of final flush fluid showed no measurable formaldehyde System was tested after recovery and found to be leak-free

Flight animal feces were watery and as a result, about 30 g (dry weight) soaked into couch padding outside feces collector (fig 1) Putrefaction products from these feces would not be drawn into fecal can, but would enter cabin atmosphere

Observers reported an odor of ammonia after the cabin was opened

During first 7 days of orbital flight, monkey 470 evinced reduction in heart rate and somewhat shallow breathing Body temperature also decreased On eighth day, heart and breathing rates decreased further to very low values, and flight was terminated After spacecraft recovery, monkey's condition was semicomatose, but improved somewhat until sudden expiration 12 hr after recovery Animal apparently suffered no breathing irregularity and was not nauseated before or after recovery Pathological examination showed no kidney damage or other evidence of toxic gas More complete discussion is given in reference 3

6 Tests B3 and B3a Heavy particle dosimeter consisted of layers of plastic sheet materials For test B3, unit that had been in cabin during first period of test A1 (with monkey 479) was placed in small chamber at 35±3° C at pressure of 18 7 mm Hg below ambient Unacceptable contaminant concentrations resulted (table 5) Components were then tested separately (test B3a) to determine which material(s) was source of contaminants

7 Test B4 Subsequent to test B3, the dosimeter design was changed so that plastic sheets were enclosed in sealed aluminum case Seal (Dupont "Nordell") was only material exposed to cabin atmsophere Unit was vibration and shock tested and then checked for leakage before test B4 was run Same unit was used in flight

8 Tests C1 and C2 See figure 3 for test setup Different chambers were used Monkey and restraint garment used in test C1 had been exposed to all operating room and other preflight environments in proper time and sequence but no actual operations were performed For test C2, monkey and restraint garment had gone through complete preflight preparation procedure Condition of the animals was monitored visually and by means of implanted sensors Both were in good health during and after test

Before inserting monkeys, both chambers were sampled for 24 hr Gas flow continued uninterrupted through insertions of animals Each test had three cryogenic sample periods the first, third, and fifth 24 hr after insertion of monkey Due to changes of source gas bottles during each test, the empty chamber results are not a true baseline

Test C1 used NASA Langley Research Center cryogenic sample system, test C2 used USAF-SAM system To keep CO_2 from building up, flow rate through chambers was 4500 cc/min Sample flow rate was 300 cc/min, excess was vented

9 Test D3 This test specimen was the spare flight set of LiOH/charcoal cans Tested outside spacecraft (unlike tests D1 and D2), external heat could be applied by means of heat lamps Wall temperatures were between 27° and 32° C For this test, the assemblies were flushed with N_2 at 200 cc/min for 2 min before starting cryogenic sampling Otherwise, procedure was same as for test D1 (see fig 2 for configuration difference) The fiberglass epoxy can shells were the same ones used during test A1, but had been cleaned and reloaded

10 Tests E1 and E2 Test setup is shown in figure 5 For test E1, specimen was unused charcoal from same lot as flight charcoal For test E2, specimen was sample of charcoal used during test A1 Sample size was 5 80 g for test E1, 6 19 g for test E2 Flow through sample was same as for flow through spacecraft charcoal (215 cc/min) Trichloroethylene was added to N_2 supply tank and concentration was found to be 4 5 ppm by gas chromatography Outlet from charcoal was fed directly into chromatograph, which could detect trichloroethylene at concentration of 0 01 ppm None detected for either test For test E1, flow was continued for 117 5 hr, test E2 was run for 41 5 hr

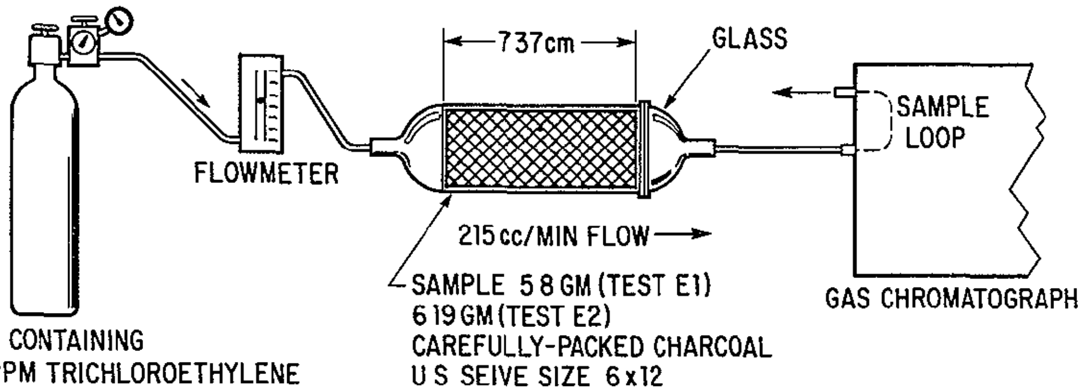

Figure 5 – Test setup for tests E1 and E2

Results are as follows

	Test E1 (117 5 hr)	Test E2 (41 5 hr)
Calculated amount of trichloroethylene adsorbed, mg	36 7	12 9
Concentration of trichloroethylene, mg/g	6 3	2 09
Percent of total capacity, assuming trichloroethylene was the only adsorbed material, per ref 10	6 5	2 1

11 Tests F4, F5, and F7 To obtain these samples, each used charcoal bed was divided into inlet and outlet halves (outlet was closest to LiOH) and each half was then subdivided to obtain samples for analysis For test F7, sample identified as "total charcoal mix" in table 9 was outlet half mixed with half of inlet charcoal half Samples of this mix represent total charcoal weighted to emphasize outlet end

12 Test F8 Amberlyst resin (Rohm and Haas) from flight trace-gas removal assembly was tested for ammonia content two ways One sample was stripped with HCl and resultant was analyzed by Nessler's reaction This gave 1 94 percent ammonia by weight of Amberlyst Residue from stripping was analyzed by C-H N analyzer and no residual ammonia was found Other samples were ground in a shatter box, tested in a C H N analyzer, and the average of five tests gave 2 24 percent ammonia by weight Latter figure is used in report Total weight of flight Amberlyst was 19 504 g

13 Test G This designation covers a series of tests of source gases

Test G1 Eighteen liters of gas from three O_2 and one N_2 bottle obtained from supplier who provided bottles used during test A1 were analyzed and found to contain very low contaminant levels – all were at or below threshold of detection

Test G2 Breathing air bottles provided at KSC for test series B and C by an outside supplier were sampled and found to contain surprisingly high concentration of contaminants 0 04 ppm trichloroethylene was found in one bottle, and an N_2 bottle used in test series D was found to contain 0 01 ppm Freon 113, 0 004 ppm trichloroethylene, and an unidentified halogen at 0 04 ppm expressed as Freon 12 Specification for cleaning gas bottles at KSC suggests use of trichloroethylene, this probably accounts for some of the contamination

Test G3 Gas supplied for filling onboard O_2 and N_2 tanks for flight was sampled and tested before spacecraft tanks were filled Liquid O_2 was of high purity Nitrogen and recovery/reentry O_2 were tested only to certification level, which showed total hydrocarbons as less than 1 0 ppm expressed as methanol More stringent analysis was not required because significant amount of nitrogen would enter cabin only if a large cabin leak occurred, and recovery O_2 was a short-term supply only

14 Test H This designation represents a series of air samples taken (a) in the laboratories at KSC where monkeys were prepared, (b) in the small container (monkey transporter) used to transport animal to launch pad, (c) in "greenhouse" surrounding the spacecraft on launch pad and (d) in the spacecraft contractor's manufacturing facility Ambient concentrations found for all except monkey transporter and laboratory were below 1 ppm of hydrocarbons expressed as methane Laboratory total hydrocarbons for one sample were only about 1 4 mg/m^3 with largest component being acetone at 0 10 ppm Monkey transporter included a liquid air supply bottle which served to induce external air flow through the container With this loop operating, the following concentrations were obtained (ambient air levels have been subtracted)

Acetone	0 45 ppm
Freon 113	051 ppm
Isopropanol	028 ppm
1,1,1 trichloroethane	0004 ppm
Total other compounds – less than ambient air	

The monkey was exposed to transporter environment for less than 1 hr

15 Test J1 As described for test A8 (note 5), the sample bottles and fittings used for the recovery samples were of questionable cleanliness One fitting was therefore tested by drawing a sample of room air through it into same size sample bottle as used for the recovery sample Simultaneous sample of room air was taken into another bottle without a fitting Results are as follows (presented in comparison to results taken at recovery through same fitting) These results are different from those reported for test A8 in table 4 because only maximum for all samples is reported in table 4

Compound	Test J1, less room air levels	Recovery sample, test A8
Dichloromethane	5 29 ppm	0 48 ppm
Freon 113	0 19 ppm	8 00 ppm
Trichloroethylene	N D (<0 003 ppm)	0 12 ppm
Tetrachloroethylene	N D (<0 003 ppm)	0 04 ppm
Total hydrocarbons	0 37 ppm as hexane	19 0 ppm as hexane*

*Obtained by summation

Changes in relative concentrations of Freon 113 and dichloromethane are probably due to lengthy storage of disconnect in contaminated container (test J3) During storage between tests A8 and J3, Freon 113 may have evaporated from disconnect, and dichloromethane may have been adsorbed from container

16 Test J2 A sample of vinyl tape used throughout spacecraft was tested to identify *potential* contaminants Approximately 10 g of tape was cryogenically cooled in a 5 cc glass container under 737 mm Hg vacuum for 1 hr Efflux from container was fed into a mass spectrometer as the specimen warmed These test conditions were designed to obtain more offgassing products than would be obtained from normal application in spacecraft The spacecraft contractor also tested this material, but found no contaminants above background level Compounds found in test J2 were not quantitated but in order of relative concentration are as follows

Methyl cyclohexane
Toluene
1 dimethyl cyclopentene
3,3 dimethyl pentane
2,3 dimethyl pentane
3 methyl pentane
Xylene
2-butanone
Dimethyl cyclohexane
1 methyl - 2 ethylbenzene

Trace quantities of following were observed

Freon 113
Freon 12
Chloroform
Trichloroethylene

TABLE 3 – RESULTS OF CLOSED CABIN TESTS OF PROTOTYPE SPACECRAFT (TEST A1)
[All results in ppm unless noted]

Restricted compounds	Safe limit	First period – monkey no 479 time after cabin closed hr			Second period – monkey no 453 time after cabin closed, hr																Final period – monkey no 453 time after cabin closed hr		
		0 25	198	207 5	0 25	27	50 5	74-96 5 three samples	108 5	120 5 168 5 four samples	180 5	192 5	216 5	228 5	240 5	264 5	288 5	312 5 336 5 two samples	360 8	375	0 25 16 8 two samples	40 5	52 5
Acetone	300																						
Alcohol n butyl	10																						
Alcohol ethyl	100	ND	ND	ND	ND	ND	Trace	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Alcohol isopropyl	50																						
Alcohol methyl	10																						
Total hydrocarbons (less CH_4)	70 mg/m³																						
Ammonia	25	ND	3 2	ND	ND	ND	4 5	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Benzene	1 0																						
2 butanone	20																						
Carbon monoxide	25	ND	ND	ND	ND	ND	20	10 15	9	10-12	7	10	10	8	10	13 5	16	15 17	15	12	ND	11	9
Cis dichloroethylene	0 1										ND			ND						ND		ND	ND
Chloroform	5 0	ND	Trace	ND	Trace	ND	ND	ND	ND	ND	0 06	ND	ND	0 02	ND	ND	ND	ND	ND	ND	ND	0 04	0 02
Dichloroacetylene	0 01										ND			ND						ND		ND	ND
Dichloromethane	25										ND			ND						ND		ND	ND
Dioxane	10																						
Ethyl acetate	40																						
Ethylene glycol	20																						
Ethylene oxide	5 0	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND
Fluorophosgene	0 01										ND			ND						ND		ND	ND
Formaldehyde	0 1	0 4*	0 2*	0 2*	ND	ND	ND	ND	ND	ND		0 2*	0 15*		ND	0 44*	0 31*	ND	0 31*	0 27*	ND	ND	0 15*
Freon 11	5 0										0 03			ND						0 07		0 04	0 04
Freon 12	200										0 18			0 04						0 36		0 27	0 29
Freon 113	150	ND	ND	ND	ND	Trace	ND	ND	Trace	ND	0 42	ND	ND	0 90	ND	ND	ND	ND	ND	0 88	ND	0 67	0 68
Freon 114	200										ND			ND						ND		ND	ND
Hydrogen chloride	1 0																						
Hydrogen fluoride	0 1																						
Hydrogen sulfide	20	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND
2 methyl butanone	20																						
Mercury	0 01 mg/m³																						
Monochloroacetylene	0 01										ND			ND						ND		ND	ND
Ozone	0 02								ND														
Phosgene	0 05										ND			ND						ND		ND	ND
Sulfur dioxide	1 0																						
Trans-dichloroethylene	0 1										ND			ND						ND		ND	ND
1 1 1 trichloroethane	5 0										ND			ND						ND		ND	ND
Trichloroethylene	0 1										0 14			0 01						ND		ND	ND
Vinylidene chloride	0 1										ND			ND						ND		ND	ND
Total chlorides	25 mg/m³										6 9 mg/m³			3 7 mg/m³								4 6 mg/m³	4 4 mg/m³
Halogenated hydrocarbons	–																						
Unknowns – chlorinated	–										ND			0 07 mg/m³						ND		0 19 mg/m³	0 17 mg/m³

ND – none detected
*Total aldehydes as formaldehyde

TABLE 3 – RESULTS OF CLOSED CABIN TESTS OF PROTOTYPE SPACECRAFT (TEST A1) – Concluded

[All results in ppm unless noted]

Other compounds	First period – monkey no 479 time after cabin closed hr			Second period – monkey no 453 time after cabin closed hr																Final period – monkey no 453 time after cabin closed hr		
	0 25	198	207 5	0 25	27	50 5	74 96 5 three samples	108 5	120 5 168 5 four samples	180 5	192 5	216 5	228 5	240 5	264 5	288 5	312 5 336 5 two samples	360 8	375	0 25 16 8 two samples	40 5	52 5
Acetaldehyde								*						*		*		*		*		
Acetate butyl																						
Acetate n butyl																						
Acetate cellosolve																						
Acetate methyl																						
Acetate n propyl																						
Acetonitrile																						
Alcohol isobutyl																						
Alcohol sec butyl																						
Alcohol tert butyl																						
Alcohol capryl																						
Alcohol n pentyl																						
Alcohol 2 propyl																						
Alcohol n propyl																						
Aromatic hydrocarbons C_9																						
Aromatic hydrocarbons C_{10}																						
Benzaldehyde	*			*			*		*		*							*		*	*	
Carbon tetrachloride										ND			ND						ND		ND	ND
Chlorobenzene										ND			ND						ND		ND	ND
Chlorotrifluoroethylene										see Freon 22			see Freon 22						see Freon 22		see Freon 22	see Freon 22
Cyclohexane																						
Cyclohexene																						
Decalin																						
Dichlorobenzene										ND			ND						ND		ND	ND
1 1 dichloroethane										ND			ND						ND		ND	ND
1 2 dichloroethane										ND			ND						ND		ND	ND
Dimethyl cyclohexane																						
Dimethyl disulfide																						
Dimethyl sulfide																						
Ethyl benzene																						
Ethylene glycol monoethyl ether																						
Ethylene glycol monomethyl ether																						
Freon 21										ND			ND						ND		ND	ND
Freon 22										0 36			0 04						0 10		0 15	0 13
Furan																						
n heptane																						
n hexane																						
Hydrocarbons C_1 C_2 C_3 C_4-C_5																						
Indene																						
Isoprene																						
Methane																						
Methyl cyclohexane																						
Methyl cyclopentane																						
Methyl isobutyl ketone																						
Methyl propenyl ketone																						
Mesitylene																						
n-octyne																						
Paraffins-C_6																						
Paraffins C_7																						
Pinene																						
Silicones																						
Styrene																						
Tetrachloroethane										ND			ND						ND		ND	ND
Tetrachloroethylene										ND			0 02						0 02		ND	ND
Toluene																						
Trimethyl hexane																						
m xylene																						
o-xylene																						
Unknowns nonchlorinated	ND	ND	ND	ND	ND	ND	ND	ND	ND		ND	ND		ND	ND	ND	ND	ND	ND	ND	ND	ND

ND – None detected
*See listing for formaldehyde

TABLE 4 – TABULATION OF CLOSED CABIN TEST RESULTS FOR FLIGHT SPACECRAFT (TESTS A2, A3, A4, A5, A6, A7, AND A8)

[All results in ppm unless noted]

Restricted compounds	Safe limit	Sample time, hr after cabin closure														
		Test A2			Test A3		Test A4			Test A5			Test A6		Test A7	Test A8
		0.3	87.8	110.5	14.5	120	0.2	12	24	0.2	240	601	0.75	45	0.5	249.2
Acetone	300						0.17	0.030	0.046	ND	Trace	Trace	0.050	0.063	2.36	1.17
Alcohol n butyl	10						0.006	0.043	0.036	ND	ND	ND	0.019	0.030	0.021	0.023
Alcohol, ethyl	100						0.027	0.43	0.42	2.0	2.0	2.0	0.022	0.65	0.97	5.18
Alcohol, isopropyl	50						0.057	0.11	0.93	ND	ND	ND	0.028	0.023	0.79	1.34
Alcohol, methyl	10						ND	ND	ND	ND	ND	ND	ND	ND	0.15	0.14
Total hydrocarbons (less CH_4)	70 mg/m³						7.6 mg/m³	5.8 mg/m³	6.0 mg/m³				ND	23 mg/m³	1.2 mg/m³	5.4 mg/m³*
Ammonia	25	ND		ND										ND	ND	262
Benzene	1.0						0.014	0.008	0.014	ND	ND	ND	0.022	0.004	0.009	0.032
2 butanone	20						ND	0.009	ND	ND	ND	ND	0.009	0.064	0.009	0.034
Carbon monoxide	25	ND		10								-	ND	ND	ND	20
Cis dichloroethylene	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Trace	ND	ND
Chloroform	5.0	ND	0.08	0.06	1.3	2.9	0.03	0.12	0.42	0.10	2.8	0.4	Trace	0.70	0.080	ND
Dichloroacetylene	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dichloromethane	25	ND	ND		0.3	ND	ND	<0.00003	<0.00003	ND	ND	ND	<0.0003	ND	ND	0.48
Dioxane	10						0.007	ND	0.002	ND	ND	ND	0.009	ND	0.001	0.14
Ethyl acetate	40						ND	ND	ND	ND	ND	ND	ND	Trace	0.013	0.027
Ethylene glycol	20						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylene oxide	5.0	ND		ND					ND				ND	ND	ND	ND
Fluorophosgene	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Formaldehyde	0.1	ND		ND										0.05**	0.54**	0.84**
Freon 11	5.0	ND	0.08	ND	0.2	0.93	<0.00002	0.005	0.06	0.06	4.1	1.5	0.01	0.74	0.05	0.20
Freon 12	200	0.05	0.40	0.05	18.9	169	0.02	ND	0.17	ND	3.9	ND	0.4†	0.92	0.16	0.19
Freon 113	150	9.5	1.1	0.97	3.0	3.1	1.2	0.13	0.16	0.40	3.8	0.6	0.1	1.1	0.091	160
Freon 114	200	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.003	ND	ND
Hydrogen chloride	1.0															
Hydrogen fluoride	0.1															
Hydrogen sulfide	20	ND		ND										ND	ND	ND
2 methyl butanone	20						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mercury	0.01 mg/m³								ND							
Monochloroacetylene	0.01	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ozone	0.02															
Phosgene	0.05	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Sulfur dioxide	1.0															
Trans dichloroethylene	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Trace	ND	ND
1 1 1 trichloroethane	5.0	ND	ND	ND	ND	0.57	0.004	0.027	0.020	0.025	0.66	0.15	0.007	0.20	0.0002	0.90
Trichloroethylene	0.1	0.05	0.01	ND	ND	0.13	0.009	<0.00002	0.009	0.05	0.6	0.05	<0.0002	<0.0002	0.005	0.90
Vinylidene chloride	0.1	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	Trace	ND	0.021
Total chlorides	25 mg/m³															
Halogenated hydrocarbons	–												ND	ND	ND	90
Unknowns chlorinated	–	ND	0.17 mg/m³‡	0.21 mg/m³‡	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	5.1 mg/m³‡

ND – none detected
* Less Freon 113 and methane
** Total aldehydes as formaldehyde
† Includes two other unidentified freons
‡ Concentration of Cl^- only

TABLE 4 – TABULATION OF CLOSED CABIN TEST RESULTS FOR FLIGHT SPACECRAFT (TESTS A2, A3, A4, A5, A6, A7, AND A8) – Concluded

[All results in ppm unless noted]

Other compounds	Sample time hr after cabin closure														
	Test A2			Test A3		Test A4			Test A5			Test A6		Test A7	Test A8
	0.3	87.8	110.5	14.5	120	0.2	12	24	0.2	240	601	0.75	45	0.5	249.2
Acetaldehyde	*	*	*									ND	0.005	*	0.002
Acetate butyl						0.004	0.0008	0.004	ND	ND	ND	ND	0.002	0.025	0.008
Acetate n butyl						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acetate cellosolve						0.001	ND	ND	ND	ND	ND	ND	ND	ND	ND
Acetate methyl						<0.00003	0.062	0.039	ND	ND	ND	ND	ND	ND	0.002
Acetate n propyl						0.036	ND	ND	ND	ND	ND	0.043	ND	ND	ND
Acetonitrile						ND	ND	ND	ND	ND	ND	0.0002	0.095	0.014	0.003
Alcohol isobutyl						0.006	0.033	0.002	ND	ND	ND	0.015	0.015	0.015	0.023
Alcohol sec-butyl						0.012	0.001	0.004	ND	ND	ND	0.009	ND	0.014	0.16
Alcohol tert butyl						0.019	0.049	0.043	ND	ND	ND	ND	0.042	ND	0.003
Alcohol capryl						ND	ND	ND	ND	ND	ND	0.12 mg/m^3	ND	ND	0.03 mg/m^3
Alcohol n pentyl						ND	ND	ND	ND	ND	ND	0.004	ND	0.002	0.016
Alcohol 2 propyl						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Alcohol n propyl						ND	ND	ND	ND	ND	ND	0.043	ND	ND	ND
Aromatic hydrocarbons-C_9						0.002 mg/m^3	0.004 mg/m^3	0.034 mg/m^3	ND	ND	ND	0.19 mg/m^3	0.037 mg/m^3	0.025 mg/m^3	0.055 mg/m^3
Aromatic hydrocarbons-C_{10}						0.005 mg/m^3	0.017 mg/m^3	0.10 mg/m^3	ND	ND	ND	0.26 mg/m^3	0.093 mg/m^3	0.047 mg/m^3	0.01 mg/m^3
Benzaldehyde	*	*	*									ND	ND	*	0.005
Carbon tetrachloride	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Chlorobenzene	ND	ND	ND	ND	ND	0.0008	0.005	0.004	ND	ND	ND	ND	ND	ND	0.012
Chlorotrifluoroethylene	See Freon 22			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.4
Cyclohexane						ND	ND	ND	ND	ND	ND	ND	0.003	0.003	ND
Cyclohexene						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Decalin						0.0009	ND	0.001	ND	ND	ND	ND	ND	ND	ND
Dichlorobenzene	ND	ND	ND	ND	ND	0.0008	0.0005	<0.00002	ND	ND	ND	0.002	ND	ND	<0.0002
1,1 dichloroethane	ND	ND	ND	ND	ND	ND	ND	ND	0.02	ND	ND	ND	ND	ND	ND
1,2 dichloroethane	ND	ND	ND	0.06	1.3	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dimethyl cyclohexane						0.005	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dimethyl disulfide						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Dimethyl sulfide						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethyl benzene						0.001	ND	ND	ND	ND	ND	0.0005	ND	0.009	0.022
Ethyl glycol monoethyl ether						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Ethylene glycol monomethyl ether						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Freon 21	ND	ND	ND	ND	ND	Trace	ND	ND	ND	ND	ND	ND	ND	ND	ND
Freon 22	0.13	0.13	0.13	ND	ND	ND	ND	ND	ND	ND	ND	<0.0003	ND	ND	ND
Furan						0.031	0.005	ND	ND	ND	ND	0.023	ND	0.015	0.031
n heptane						0.002	ND	ND	ND	ND	ND	0.034	ND	ND	ND
n hexane						0.0003	ND	ND	ND	ND	ND	0.001	Trace	Trace	0.017
Hydrocarbons C_1-C_2-C_3-C_4-C_5						ND	ND	ND	ND	ND	ND	0.17 mg/m^3	0.2 mg/m^3	0.05 mg/m^3	11.2 mg/m^3
Indene						0.001	ND	ND	ND	ND	ND	ND	ND	ND	ND
Isoprene						ND	ND	ND	ND	ND	ND	ND	ND	0.003	ND
Methane														ND	36.0
Methyl cyclohexane						0.002	0.003	ND	ND	ND	ND	0.004	ND	0.062	0.004
Methyl cyclopentane						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Methyl isobutyl ketone						<0.00002	0.016	0.011	ND	ND	ND	0.010	0.041	0.012	0.024
Methyl propenyl ketone						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Mesitylene						ND	ND	ND	ND	ND	ND	ND	ND	ND	0.010
n-octyne						ND	ND	ND	ND	ND	ND	0.003	0.002	ND	ND
Paraffins C_6						0.02 mg/m^3	ND	ND	ND	ND	ND	0.007 mg/m^3**	0.009 mg/m^3	ND	ND
Paraffins-C_7						ND	ND	ND	ND	ND	ND	0.005 mg/m^3 †	ND	ND	ND
Pinene						ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Silicones						ND	ND	ND	ND	ND	ND	ND	ND	0.023 mg/m^3	0.002 mg/m^3
Styrene						0.004	0.007	0.009	ND	ND	ND	0.004	ND	0.003	0.024
Tetrachloroethane	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	<0.0001
Tetrachloroethylene	ND	ND	ND	ND	ND	0.007	0.033	0.080	ND	ND	ND	<0.0001	0.004	<0.0001	0.039
Toluene						0.005	0.018	0.013	ND	ND	ND	0.008	0.082	0.018	0.16
Trimethyl hexane						0.007	ND	ND	ND	ND	ND	0.007	0.003	0.030	0.001
m xylene						0.029	0.006	0.007	ND	ND	ND	0.015	0.013	0.012	0.012
o-xylene						ND	ND	0.003	ND	ND	ND	0.033	0.004	0.003	0.009
Unknowns nonchlorinated						0.56 mg/m^3	0.03 mg/m^3	0.23 mg/m^3	ND	ND	ND	0.11 mg/m^3	0.04 mg/m^3	0.05 mg/m^3	0.08 mg/m^3

ND – None detected

* See formaldehyde

** Exclusive of hexane

† Exclusive of heptane

TABLE 5 – TABULATION OF COMPONENT TEST RESULTS (B1 THROUGH B6) EMPTY CHAMBER ATMOSPHERE CONCENTRATIONS HAVE BEEN SUBTRACTED FROM RESULTS

[All results in ppm unless noted]

Restricted compound	Safe limit	Test B1 Experiment electronics	Test B2 Monkey couch	Test B3 Heavy particle dosimeter		Test B3a Heavy particle dosimeter components 48 hr samples					Test B4 Flight H P dosimeter	Test B5 Electric food dispenser	Test B6 Electric food dispenser
		24 hr	24 hr	48 hr	240 hr	Emulsion	Lexan	Adhesive	Tape	Cellulose triacetate	36 hr	24 hr	24 hr
Acetone	300	ND	ND	ND	7 2	ND	1 3	7 6	1 8	31	ND	≤6 0	ND
Alcohol n butyl	10											High >10	
Alcohol ethyl	100		Total									≤1 6	≤7 6
Alcohol isopropyl	50		<1 5									ND	ND
Alcohol methyl	10												
Total hydrocarbons	70 mg/m³	7 8 mg/m³	4 3 mg/m³								8 5 mg/m³	40 mg/m³	23 mg/m³
Ammonia	25												
Benzene	1 0	ND	ND								ND	ND	ND
2 butanone	20			ND	ND	ND	ND	ND	ND	ND		≤0 5	≤0 1
Carbon monoxide	25			ND	ND	ND	ND	ND	ND	ND			
Cis dichloroethylene	0 1	ND	ND								≤0 02	ND	ND
Chloroform	5 0			72	48	1 7	44	4 0	71	311	≤0 14		
Dichloroacetylene	0 01										ND		
Dichloromethane	25		0 03										
Dioxane	10		ND										
Ethyl acetate	40												
Ethylene glycol	20												
Ethylene oxide	5 0												
Fluorophosgene	0 01	ND	ND								ND	ND	ND
Formaldehyde	0 1												
Freon 11	5 0	ND	ND								ND	ND	ND
Freon 12	200	0 08									≤0 004	≤0 003	≤0 003
Freon 113	150	0 01									≤0 001	≤0 1	≤0 1
Freon 114	200	ND	ND								ND	ND	ND
Hydrogen chloride	1 0												
Hydrogen fluoride	0 1												
Hydrogen sulfide	20												
2 methyl butanone	20	ND	ND								ND	ND	ND
Mercury	0 01 mg/m³												
Monochloroacetylene	0 01	ND	ND								ND	ND	ND
Ozone	0 02												
Phosgene	0 05	ND	ND								ND	ND	ND
Sulfur dioxide	1 0												
Trans dichloroethylene	0 1	ND	ND								ND	ND	ND
1 1 1 trichloroethane	5 0		0 04	ND	ND	ND	ND	ND	ND	ND	≤0 01	≤0 02	≤0 02
Trichloroethylene	0 1	ND*	ND*	≤0 4	28	2 8	8 2	11	9 0	58	≤0 02	≤0 01	≤0 01
Vinylidene chloride	0 1			ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Total chlorides	25 mg/m³												
Halogenated hydrocarbons	–		ND								ND		
Unknowns chlorinated	–	ND		5 15	5 15	ND	5 15	5 15	5 15	5 15		0 1 mg/m³	0 1 mg/m³

ND – None detected

*Empty chamber atmosphere concentration was higher than test concentration

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TABLE 5 – TABULATION OF COMPONENT TEST RESULTS (B1 THROUGH B6) EMPTY CHAMBER ATMOSPHERE CONCENTRATIONS HAVE BEEN SUBTRACTED FROM RESULTS – Concluded

[All results in ppm unless noted]

Other compounds	Test B1 Experiment electronics	Test B2 Monkey couch	Test B3 Heavy particle dosimeter		Test B3a Heavy particle dosimeter components 48 hr samples					Test B4 Flight H P dosimeter	Test B5 Electric food dispenser	Test B6 Electric food dispenser
	24 hr	24 hr	48 hr	240 hr	Emulsion	Lexan	Adhesive	Tape	Cellulose triacetate	36 hr	24 hr	24 hr
Acetaldehyde	ND	ND										
Acetate butyl										ND	ND	ND
Acetate n butyl												
Acetate cellosolve												
Acetate methyl												
Acetate n propyl												
Acetonitrile												
Alcohol isobutyl												
Alcohol sec butyl												
Alcohol tert butyl												
Alcohol capryl												
Alcohol n pentyl												
Alcohol 2 propyl												
Alcohol n propyl												
Aromatic hydrocarbons C_9												
Aromatic hydrocarbons C_{10}												
Benzaldehyde												
Carbon tetrachloride										ND	ND	ND
Chlorobenzene												
Chlorotrifluoroethylene												
Cyclohexane												
Cyclohexene												
Decalin												
Dichlorobenzene												
1 1 dichloroethane												
1 2 dichloroethane												
Dimethyl cyclohexane												
Dimethyl disulfide												
Dimethyl sulfide												
Ethyl benzene												
Ethylene glycol monoethyl ether												
Ethylene glycol monomethyl ether												
Freon 21												
Freon 22												
Furan												
n heptane												
n hexane											<5.4	<0 1
Hydrocarbons C_1-C_2-C_3 C_4-C_5											ND	ND
Indene												
Isoprene												
Methane										18		
Methyl cyclohexane	ND	ND								ND	ND	ND
Methyl cyclopentane												
Methyl isobutyl ketone												
Methyl propenyl ketone												
Mesitylene												
n octyne												
Paraffins-C_6												
Paraffins C_7												
Pinene												
Silicones												
Styrene												
Tetrachloroethane												
Tetrachloroethylene												
Toluene	<1 0										<1 6	<0 1
Trimethyl hexane	ND										ND	ND
m xylene	<1 0											
o xylene												
Unknowns nonchlorinated	ND		ND	ND	ND	ND	ND	ND	ND			

ND – None detected

TABLE 6 – TABULATION OF MONKEY TEST RESULTS (C1 AND C2)
[All results in ppm unless noted]

Restricted compounds	Safe limit	Test C1				Test C2			
		Empty chamber	With monkey			Empty chamber	With monkey		
		24 hr	24 hr	72 hr	120 hr	24 hr	24 hr	72 hr	120 hr
Acetone	300	0 042	⩽3 3	0 030	0 0004	0 012	0 040	0 019	0 006
Alcohol n butyl	10	009	0 004	002	0005	00007	002	006	001
Alcohol, ethyl	100	037	058	04	004	002	011	064	008
Alcohol isopropyl	50	031	006	006	007	001	029	008	005
Alcohol methyl	10	ND	ND	ND	ND	ND	002	ND	ND
Total hydrocarbons (less CH_4)	70 mg/m^3	0 86 mg/m^3	2 8 mg/m^3	2 7 mg/m^3	2 4 mg/m^3	1 3 mg/m^3	3 6 mg/m^3	2 8 mg/m^3	5 7 mg/m^3
Ammonia	25						ND		1 1
Benzene	1 0	0 002	0 004	0 0004	0 00003	0 0002	0 0003	0 0001	0 0002
2 butanone	20	ND	0001	ND	ND	< 00003	ND	0002	00007
Carbon monoxide	24	~0 3	ND		0 7	0 7		ND	ND
Cis dichloroethylene	0 1	ND			ND	ND	0 02		
Chloroform	5 0					<0 00002	ND		
Dichloroacetylene	0 01		↓	↓		ND	ND		
Dichloromethane	25	↓	0 021	0 003	↓	<0 00003	0 011	↓	
Dioxane	10	0 001	0004	0008	0 0003	0002	0007	0 0004	↓
Ethyl acetate	40	001	0001	003	0001	00008	0007	0003	0 0001
Ethylene glycol	20	ND	ND	ND	ND	ND	ND	ND	ND
Ethylene oxide	5 0								
Fluorophosgene	0 01	ND	ND	ND	ND	ND	ND	ND	ND
Formaldehyde	0 1								
Freon 11	5 0	0 002	ND	0 001	ND	0 001	0 001	ND	ND
Freon 12	200	ND	↓	ND	↓	ND	ND	↓	↓
Freon 113	150	0 002	0 0005	0 002	0 001	0 001	0 001	0 001	0 0006
Freon 114	200	ND	ND	ND	ND	ND	00003	ND	ND
Hydrogen chloride	1 0						ND		
Hydrogen fluoride	0 1			↓			↓		↓
Hydrogen sulfide	20								
2 methyl butanone	20	ND	ND	ND	ND	ND	ND	ND	ND
Mercury	0 01 mg/m^3								
Monochloroacetylene	0 01	ND	ND	ND	ND	ND	ND	ND	ND
Ozone	0 02								
Phosgene	0 05	ND	ND	ND	ND	ND	ND	ND	ND
Sulfur dioxide	1 0								
Trans dichloroethylene	0 1	ND	ND	ND	ND	ND	*	ND	ND
1,1,1 trichloroethane	5 0	0 014	0 011	0 003	0 0009	0 07	0 002	0 002	0 002
Trichloroethylene	0 1	02	0007	003	0004	004	02	0 0007	0005
Vinylidene chloride	0 1	001	ND	ND	0008	0008	*	0004	0007
Total chlorides	25 mg/m^3								
Halogenated hydrocarbons	–	ND	ND	ND	ND	ND	ND	ND	ND
Unknowns chlorinated	–	↓	↓	↓	<0 00001 mg/m^3	↓	↓	0 0007 mg/m^3	0 00002 mg/m^3

ND – None detected
*Included in cis dichloroethylene concentration

TABLE 6 – TABULATION OF MONKEY TEST RESULTS (C1 AND C2) – Concluded

[All results in ppm unless noted]

Other compounds	Test C1 Empty chamber 24 hr	Test C1 With monkey 24 hr	Test C1 With monkey 72 hr	Test C1 With monkey 120 hr	Test C2 Empty chamber 24 hr	Test C2 With monkey 24 hr	Test C2 With monkey 72 hr	Test C2 With monkey 120 hr
Acetaldehyde	ND	ND	0 001	ND	ND	0 0003	ND	ND
Acetate butyl		0 001	0009	↓	↓	ND	0 0005	0 0002
Acetate n butyl		ND	ND	0 0002	0 0003	0 00007	ND	ND
Acetate cellosolve		↓	0 0001	ND	00003	ND		
Acetate methyl		0 00003	ND	0 0002	0001			
Acetate n propyl		ND	0 0008	0003	0004		↓	↓
Acetronitrile		↓	001	0005	001	↓	0 00005	0 0002
Alcohol isobutyl	↓	0.001	0007	0003	0002	0 0004	001	0006
Alcohol sec butyl	0 003	001	001	0002	0005	0006	002	002
Alcohol tert butyl	ND	ND	001	0001	00003	001	0004	001
Alcohol capryl			ND	00001	ND	ND	00003	ND
Alcohol n pentyl			0 0007	00003		↓	00009	
Alcohol 2 propyl			ND	ND		0 00008	ND	↓
Alcohol n propyl			↓	0 0004	↓	ND	0 0001	0 0001
Aromatic hydrocarbons C_9			*0 0005 mg/m³*	*0 0004 mg/m³*	*<0 0001 mg/m³*	*0 002 mg/m³*	*0 003 mg/m³*	0 004 mg/m³
Aromatic hydrocarbons C_{10}			003 mg/m³	0002 mg/m³	< 0001 mg/m³	0 0006 mg/m³	001 mg/m³	0002 mg/m³
Benzaldehyde			0 0002	0 00002	0 00004	ND	0 00007	ND
Carbon tetrachloride	↓	↓	ND	ND	ND	Trace	ND	↓
Chlorobenzene	0 0001	0 0003	0 0004	0 00002	0 00004	0 0003	0 0003	0 0001
Chlorotrifluoroethylene	ND	ND	ND	ND	ND	ND	ND	ND
Cyclohexane			0 0003	0 0001	0 00003	0 00003	0 00003	↓
Cyclohexene			ND	*ND*	*ND*	*<.00003*	*ND*	*0 00005*
Decalin	↓	↓	↓	↓	↓	ND	↓	ND
Dichlorobenzene	<0 000003	0 0001	0 0002	0 00009	0 0001	0 0005	0 0002	0 0009
1 1 dichloroethane	0001	ND	ND	ND	ND	ND	ND	ND
1 2 dichloroethane	0004	↓	↓	↓		↓	↓	↓
Dimethyl cyclohexane	004	0 00002	0 0002	0 00002		0 00009	0 00009	0 00002
Dimethyl disulfide	ND	ND	ND	001		ND	007	009
Dimethyl sulfide	↓		0 0003	00001	↓	↓	001	0009
Ethyl benzene	0 00002		001	00002	0 00002	0 0005	00007	0002
Ethylene glycol monoethyl ether	ND		<.00002	ND	ND	ND	ND	ND
Ethylene glycol monomethyl ether			< 00003					
Freon 21			ND		↓	↓	↓	
Freon 22	↓	↓	See Freon 11	↓	See Freon 11	0 0006	0 00002	↓
Furan	0 00003	0 002	0 0002	0 00001	0 00003	0 00008	ND	0 00008
n heptane	ND	ND	ND	ND	ND	ND	0 00002	00008
n hexane				0 0002	0 00003		00003	00003
Hydrocarbons C_1-C_2 C_3 C_4 C_5			↓	0 002 mg/m³	ND		0 004 mg/m³	0 002 mg/m³
Indene			0 0002	0 00002	0 00004		0 00004	ND
Isoprene			ND	ND	ND		ND	↓
Methane			↓	↓	↓	↓		
Methyl cyclohexane		↓	*0 0007*	0 00008	<0 00002	0 0003	ND	ND
Methyl cyclopentane	↓	0 0001	ND	00003	ND	00003	↓	↓
Methyl isobutyl ketone	0 001	0 001	0 003	0003	0 00008	0 0008	0 0003	0 0002
Methyl propenyl ketone	ND	ND	0002	ND	ND	ND	ND	ND
Mesitylene			0001			0 00004		
n octyne	↓	↓	ND		↓	0003		↓
Paraffins-C_6	0 002 mg/m₃	0 10 mg/m³	0 0005 mg/m³	↓	0 001 mg/m³	0 0002 mg/m³	↓	0 0003 mg/m³
Paraffins-C_7	0002 mg/m³	20 mg/m³	*ND*	*0 0001 mg/m³*	*ND*	*0003 mg/m³*	*0 0004 mg/m³*	*0002 mg/m³*
Pinene	ND	0 0002		ND		0 00002	ND	ND
Silicones	0 001 mg/m³	0 002 mg/m³	↓	↓	↓	ND	↓	↓
Styrene	0 00002	0 0001	0 0002	0 00007	<0 00002	0 0001	0 0008	0 0003
Tetrachloroethane	0006	0001	ND	ND	00008	ND	ND	00001
Tetrachloroethylene	ND	00003	0 002	0 00001	0 0005	0 002	0 0002	0002
Toluene	0 002	017	002	00008	001	001	0006	0002
Trimethyl hexane	ND	00004	ND	ND	ND	ND	ND	ND
m xylene	0 0007	0001	0 0005	0 00005	0 00004	0 0002	0 001	0 00007
o xylene	ND	001	0003	00001	00002	00002	0002	0001
Unknowns nonchlorinated	↓	0 009 mg/m³	0 006 mg/m³	0 0002 mg/m³	0 001 mg/m³	ND	0 004 mg/m³	0 002 mg/m³

ND – None detected

TABLE 7 – TABULATION OF RESULTS FROM SINGLE PASS TESTS OF SPACECRAFT CO_2 AND TRACE-GAS-REMOVAL ASSEMBLIES (TESTS D1, D2, D3, AND D4)
[All results in ppm unless noted]

Restricted compound	Safe limit	Test			
		Charcoal – LiOH			Trace gas
		D1	D2	D3	D4
Acetone	300	≤1 0	≤0 16	0 026	ND
Alcohol n butyl	10			0005	
Alcohol ethyl	100	Total	Total	007	
Alcohol isopropyl	50	≤1 0	≤0 6	016	
Alcohol, methyl	10			ND	↓
Total hydrocarbons (less CH_4)	70 mg/m³	32 8 mg/m³ (a)	7 13 mg/m³ (b)		
Ammonia	25				
Benzene	1 0	ND	ND	0 0005	ND
2 butanone	20	↓	↓	001	↓
Carbon monoxide	25				
Cis dichloroethylene	0 1	ND	ND	ND	ND
Chloroform	5 0				
Dichloroacetylene	0 01			↓	
Dichloromethane	25			0 001	
Dioxane	10			0003	
Ethyl acetate	40			ND	
Ethylene glycol	20	↓	↓	↓	↓
Ethylene oxide	5 0				
Fluorophosgene	0 01	ND	ND	ND	ND
Formaldehyde	0 1				
Freon 11	5 0	ND	ND	ND	ND
Freon 12	200	0 037	≤0 01	↓	0 02
Freon 113	150	026	≤01	0 013	(c)
Freon 114	200	ND	ND	ND	ND
Hydrogen chloride	1 0				
Hydrogen fluoride	0 1				
Hydrogen sulfide	20				
2 methyl butanone	20	ND	ND	ND	ND
Mercury	0 01 mg/m³				
Monochloroacetylene	0 01	ND	ND	ND	ND
Ozone	0 02				
Phosgene	0 05	ND	ND	ND	ND
Sulfur dioxide	1 0				
Trans dichloroethylene	0 1	ND	ND	ND	ND
1 1 1 trichloroethane	5 0	≤0 001	≤0 001	0 001	ND
Trichloroethylene	0 1	ND	≤0 002	Trace (d)	(e)
Vinylidene chloride	0 1	↓	ND	ND	ND
Total chlorides	25 mg/m³				
Halogenated hydrocarbons	–				
Unknowns chlorinated	–	ND	0 011 mg/m³ (f)	ND	(g)

ND – None detected
(a) Aromatics (disubstituted benzenes) ≤ 19 0 mg/m³ as o xylene aliphatics ≤ 38 5 mg/m³ as n hexane
(b) Aromatics (disubstituted benzenes) ≤ 1 90 mg/m³ as o xylene aliphatics ≤ 3 85 mg/m³ as n hexane
(c) Decreased from supply gas by factor of 10 to 0 001 ppm
(d) Less than 0 00002 ppm
(e) Decreased from supply gas by factor of 2 to 0 002 ppm
(f) Unidentified freon
(g) Decreased from supply gas by factor of 40 to 0 22 mg/m³

TABLE 7 – TABULATION OF RESULTS FROM SINGLE PASS TESTS OF SPACECRAFT CO_2 AND TRACE GAS REMOVAL ASSEMBLIES (TESTS D1, D2, D3, AND D4) – Concluded

[All results in ppm unless noted]

Other compounds	Test			
	Charcoal – LiOH			Trace gas
	D1	D2	D3	D4
Acetaldehyde	ND	ND	ND	ND
Acetate butyl				
Acetate n butyl				
Acetate cellosolve				
Acetate methyl				
Acetate n propyl			↓	
Acetonitrile			0 001	
Alcohol isobutyl			004	
Alcohol sec butyl			ND	
Alcohol tert butyl			↓	
Alcohol capryl			0 0002	
Alcohol n pentyl			ND	
Alcohol 2 propyl				
Alcohol n propyl				
Aromatic hydrocarbons C_9			↓	
Aromatic hydrocarbons-C_{10}			0 015 mg/m^3	
Benzaldehyde			ND	
Carbon tetrachloride				
Chlorobenzene				
Chlorotrifluoroethylene				
Cyclohexane			↓	
Cyclohexene			0 002	
Decalin			ND	
Dichlorobenzene			0 0003	
1 1 dichloroethane			ND	
1 2 dichloroethane			↓	
Dimethyl cyclohexane			0 0001	
Dimethyl disulfide			ND	
Dimethyl sulfide			↓	
Ethyl benzene			0 0007	
Ethylene glycol monoethyl ether			ND	
Ethylene glycol monomethyl ether				
Freon 21				
Freon 22				
Furan			↓	
n heptane			0 010	
n hexane			007	
Hydrocarbons C_1 C_2 C_3 C_4 C_5			0 021 mg/m^3	
Indene			ND	
Isoprene	↓	↓	↓	↓
Methane				
Methyl cyclohexane	ND	ND	0 002	ND
Methyl cyclopentane			004	
Methyl isobutyl ketone			0001	
Methyl propenyl ketone			ND	
Mesitylene			↓	
n octyne			0 0002	
Paraffins C_6			ND	
Paraffins C_7				
Pinene				
Silicones			↓	
Styrene			0 0008	
Tetrachloroethane	↓	↓	ND	
Tetrachloroethylene	3 5	≤0 4	Trace	
Toluene	≤1 0	≤0 1	0 063	
Trimethyl hexane	ND	ND	009	
m xylene			001	
o-xylene			005	
Unknowns, nonchlorinated	↓	↓	0 006 mg/m^3	↓

ND – None detected

TABLE 8 – RESULTS OF ANALYSES OF LiOH (TESTS F1, F2, AND F3)

Trace contaminants

LiOH samples were desorbed and desorbate was trapped in liquid nitrogen traps (N_2 carrier gas) Analysis was by gas chromatography specifically for the following dichloroacetylene, monochloroacetylene, phosgene, 1,1,2,2 tetrachloroethane, 1,1,1 trichloroethane, trichloroethylene, and vinylidene chloride Only the com pounds that were detected are reported herein

Contents

Analyzed by wet chemistry The $C\ell^-$ content was obtained from HCl The "normalized" $C\ell^-$ content was obtained as follows

$$C\ell^-_{norm} = \frac{C\ell^-(\text{ppm})}{\dfrac{2\times\text{mol wt LiOH}}{\text{mol wt } Li_2CO_3}(\text{wt } Li_2CO_3 \text{ per gm of sample}) + \text{wt LiOH per gm of sample}}$$

Can no 1 is the upstream can, can no 2 is the downstream can

Test F1 LiOH used during test A1

Trace contaminants

Phosgene 1 ppm (not found in any other test)

Contents

Source	LiOH, % by wt	Li_2CO_3, % by wt	H_2O, % by wt	$C\ell^-$, ppm	Normalized $C\ell^-$, ppm
Can no 1 inlet	0 8	98 5	0 7	12 5	19 3
Can no 1 middle	3 8	92 8	3 4	13 8	21 6
Can no 1 outlet	19 85	65 25	14 9	12 0	19 3

Test F2 Unused LiOH, same production run as for test F3

Trace contaminants

None detected

Contents

Source	LiOH, % by wt	Li_2CO_3, % by wt	H_2O, % by wt	$C\ell^-$, ppm	Normalized $C\ell^-$, ppm
Not applicable	99 3	0 7	0	19 0	19 05

Test F3 Flight LiOH (test A8)

Trace contaminants

Not tested

Contents

Source	LiOH, % by wt	Li_2CO_3 % by wt	H_2O, % by wt	$C\ell^-$, ppm	Normalized $C\ell^-$, ppm
Can no 1 inlet	9 3	81 7	9 0	19 9	32
Can no 1 middle	56 2	9 4	34 4	15 6	25
Can no 1 outlet	76 1	7	23 2	19 2	25
Can no 2 inlet*	96 6	7	2 7	24 3	25
Can no 2 middle*	98 2	7	1 1	24 7	25
Can no 2 outlet*	98 9	7	4	24 8	25

*Can no 2 was only open to flow for the last 17 hr of flight

TABLE 9 – RESULTS OF CHARCOAL ANALYSES (TESTS F4, F5, F6, AND F7)

Restricted compounds*	Test F4 – Used in test A1		Test F5 – Used in test A2	Test F6 – Unused charcoal		Test F7 – Used in flight (test A8)	
	Inlet end, μg/g	Outlet end, μg/g	Outlet end, μg/g	Sample 1, μg/g	Sample 2, μg/g	Inlet end, μg/g	Total charcoal mix, μg/g
Acetone		1 86	11 8	0 37		6 29	2 03
Alcohol n butyl		0 002	0 047	< 0001		006	009
Alcohol, ethyl		26	1 76	16		1 52	2 13
Alcohol, isopropyl		13	012	13		37	43
Alcohol, methyl		ND	ND	ND		2 54	70
Total hydrocarbons							
Ammonia							49 5
Benzene		0 13	1 79	0 42		1 30	025
2 butanone		012	33	ND		011	041
Carbon monoxide							
Cis dichloroethylene	ND	ND	ND	0 094	ND	ND	ND
Chloroform	ND	0 43	ND	ND	ND	0 18	0 59
Dichloroacetylene	ND	1 36**	ND	ND	ND	ND	ND
Dichloromethane	2 0	4 37	2 56	2 27	0 175	5 48	0 78
Dioxane		002	009	ND		19	10
Ethyl acetate		023	026	0068		51	17
Ethylene glycol		ND	ND	ND		ND	ND
Ethylene oxide							
Fluorophosgene	ND	ND	ND	ND	ND	ND	ND
Formaldehyde						<0 01	<3
Freon 11	0 16	0 43	See Freon 12	0 53	0 0025	1 99	30
Freon 12	1 8	33 8	3 82	7 82	2 5	1 36	ND
Freon 113	6 5	14 6	123	12 6	70	37 2	7 48
Freon 114	4 1	~<1	ND	~< 05	013	45	0006
Hydrogen chloride							
Hydrogen fluoride							
Hydrogen sulfide							
2 methyl butanone		ND	ND	ND		ND	ND
Mercury							
Monochloroacetylene	ND	ND	ND	ND	ND	ND	ND
Ozone							
Phosgene	ND	ND	ND	ND	ND	ND	ND
Sulfur dioxide							
Trans dichloroethylene	ND	ND	ND	See cis dichloroethylene	ND	ND	ND
1 1,1 trichloroethane	ND	ND	0 058	0 014	ND	0 25	0 071
Trichloroethylene	0 16	0 44	19	60	ND	1 17	86
Vinylidene chloride	ND	ND	ND	ND	ND	52	11
Total chlorides							
Halogenated hydrocarbons							
Unknowns chlorinated	ND	ND	ND	ND	ND	ND	ND

ND – None detected
* Safe limit not applicable
** Not found in any other test

TABLE 9 – RESULTS OF CHARCOAL ANALYSES (TESTS F4, F5, F6, AND F7) – Continued

Other compounds	Test A4 – Used in test A1		Test F5 – Used in test A2	Test F6 – Unused charcoal		Test F7 – Used in flight (test A8)	
	Inlet end μg/g	Outlet end μg/g	Outlet end μg/g	Sample 1 μg/g	Sample 2 μg/g	Inlet end, μg/g	Total charcoal mix μg/g
Acetaldehyde		ND	7 57	ND		ND	0 27
Acetate butyl		↓	008	↓		0 018	ND
Acetate, n butyl		↓	ND	↓		ND	↓
Acetate cellosolve		↓	↓	↓		↓	↓
Acetate methyl		0 62	↓	0 0046		0 036	↓
Acetate n propyl		012	↓	ND		ND	↓
Acetonitrile		ND	0 099	↓		0 75	0 022
Alcohol isobutyl		↓	031	↓		011	021
Alcohol sec butyl		0 005	ND	↓		047	067
Alcohol tert butyl		ND	0 026	↓		ND	ND
Alcohol capryl		↓	005	↓		↓	↓
Alcohol n pentyl		↓	ND	↓		↓	↓
Alcohol 2 propyl		↓	↓	↓		↓	↓
Alcohol n propyl		↓	↓	↓		0 025	↓
Aromatic hydrocarbons C_9		0 001	0 001	0 0003		ND	0 0001
Aromatic hydrocarbons C_{10}		ND	007	0001		0 007	ND
Benzaldehyde		↓	ND	ND		ND	↓
Carbon tetrachloride	ND	0 065	Trace	↓	ND	↓	↓
Chlorobenzene	↓	002	ND	↓	↓	↓	↓
Chlorotrifluoroethylene	See Freon 22	ND	Trace	~1	1 13	↓	↓
Cyclohexane		1 57	ND	0 13		↓	↓
Cyclohexene		ND	↓	ND		↓	↓
Decalin		↓	↓	↓		↓	↓
Dichlorobenzene	ND	↓	0 003	<0 0001	ND	↓	↓
1 1 dichloroethane	↓	↓	ND	ND	↓	↓	↓
1 2 dichloroethane	↓	↓	↓	↓	↓	↓	↓
Dimethyl cyclohexane		↓	↓	↓		↓	↓
Dimethyl disulfide		↓	↓	↓		↓	↓
Dimethyl sulfide		↓	↓	↓		↓	0 027
Ethyl benzene		0 002	0 002	0 0048		0 012	018
Ethylene glycol monoethyl ether	ND	ND	ND	ND	ND	ND	ND
Ethylene glycol monomethyl ether	↓	↓	↓	↓	↓	↓	↓
Freon 21	0 40	↓	↓	↓	↓	0 59	0 003
Freon 22	8 0	See Freon 12	↓	See Freon 12	0 57	ND	056
Furan		0 050	0 39	0 11		0 38	23
n heptane		ND	ND	ND		76	ND
n hexane		0 61	↓	0 11		031	↓
Hydrocarbons C_1 C_2 C_3 C_4 C_5		ND	103*	ND		ND	↓
Indene		↓	ND	↓		↓	↓
Isoprene		↓	↓	↓		0 34	↓
Methane							
Methyl cyclohexane		0 009	1 25	0 021		0 30	0 11
Methyl cyclopentane		ND	ND	036		074	ND
Methyl isobutyl ketone		↓	0 012	ND		013	0 044
Methyl propenyl ketone		↓	ND	↓		ND	ND
Mesitylene		↓	↓	↓		↓	0 00001
n octyne		↓	↓	↓		↓	ND
Paraffins C_6		↓	↓	↓		↓	↓
Paraffins C_7		↓	3 41	↓		↓	↓
Pinene		↓	ND	↓		↓	↓
Silicones		↓	↓	↓		0 002	↓
Styrene		0 0008	0 003	↓		004	↓
Tetrachloroethane	ND	ND	ND	↓	ND	ND	↓
Tetrachloroethylene	↓	0 067	0 057	0 084	↓	0 55	0 34
Toluene		097	3 55	26		64	044
Trimethyl hexane		ND	ND	026		30	ND
m xylene		0 0008	0 025	0026		010	0 005
o xylene		0001	006	0001		ND	0005
Unknowns, nonchlorinated		002	13	010		↓	ND
Water		16 2X10^3	18 9X10^3	5 4X10^3		46 6X10^3	47 9X10^3

ND – None detected
*Includes CO_2

Other compounds found only on charcoal samples	Test A4 – Used in test A1		Test F5 – Used in test A2	Test F6 – Unused charcoal		Test F7 – Used in flight (test A8)	
	Inlet end μg/g	Outlet end, μg/g	Outlet end μg/g	Sample 1, μg/g	Sample 2 μg/g	Inlet end, μg/g	Total charcoal mix μg/g
Acetylene		ND	ND	ND		0 051	0 16
Allene (propadiene)						ND	001
Butane						↓	11
n butane						0 001	ND
Butene 1						38	↓
Butene 2 (cis + trans)						27	0 24
C_2Cl_2	ND				ND	See Freon 11	ND
Chloroethylene	↓	↓			0 05	ND	
Cyclopentene		0 47	↓	↓		↓	↓
Dichlorodifluoroethylene	ND	~0 4	See Freon 12	~0 04	ND	0 15	0 026
Dichloroethane	↓	ND	ND	ND	↓	ND	003
Diethyl sulfide						0 071	ND
Difluoroethylene	ND				ND	ND	0 018
Dimethyl butane						0 0003	ND
Dimethyl ether	ND				ND	ND	0 002
Ethane						0 006	0 054
Ethyl chloride	ND				ND	ND	003
Ethylene						0 15	10
Ethyl fluoride	ND				ND	011	00001
Fluorochloroethylene						ND	24
Fluorochloromethane					↓		90
Freon 13					0 075		ND
Freon 14		↓		↓	ND		0 0002
Freon 112		~0 05		~0 05	↓		ND
Freon 115	↓	ND		ND	0 013		↓
Hexene 2		0 080		0 030			0 013
Iospentane		1 16		ND		↓	0007
Methyl pentane		ND				0 058	36
n nonane		0 002				ND	ND
Pentafluoroethane	ND	ND			ND		0 00001
Pentane		↓		↓			012
n pentane		1 21		0 44			ND
Pentene		ND		ND			0 028
Pentene 1		1 40		0 63			ND
Propane		ND		ND		↓	0 0001
Propylene		30 8		1 50		0 47	0 28
Tetrahydrofuran		019		ND		ND	ND
Trifluorochloroethylene	ND	~5		ND	ND	3 49	0 82
Trifluoroethylene		ND				073	072
Trifluoromethane	↓	↓	↓	↓	↓	ND	00009
Total of all compounds listed in Table 9							
Total halogenated	23 12	62 014	129 688	25 152	5 328	53 464	12 675
Total nonhalogenated (less water)	Not tested for	40 443	32 299*	4 402	Not tested for	17 964	60 353
Percentage of total halogenated in one compound	35 (Freon 22)	55 (Freon 12)	95 (Freon 113)	50 (Freon 113)	47 (Freon 12)	70 (Freon 113)	59 (Freon 113)

ND – None detected

*C_2 C_3 C_4 C_5 hydrocarbons not added due to inclusion of unknown amount of CO_2

TABLE 10 – COMPOUNDS FOUND IN RECOVERY SAMPLE-BOTTLE CONTAINER (TEST J3)
[All results in ppm unless noted]

Restricted compound	Safe limit	Result
Acetone	300	41 6
Alcohol, n-butyl	10	0 036
Alcohol, ethyl	100	ND
Alcohol, isopropyl	50	1 15
Alcohol, methyl	10	0 011
Total hydrocarbons (less CH_4)	70 mg/m^3	
Ammonia	25	
Benzene	1 0	0 003
2-butanone	20	0 003
Carbon monoxide	25	
Cis dichloroethylene	0 1	ND
Chloroform	5 0	ND
Dichloroacetylene	0 01	ND
Dichloromethane	25	ND
Dioxane	10	0 002
Ethyl acetate	40	ND
Ethylene glycol	20	ND
Ethylene oxide	5 0	
Fluorophosgene	0 01	ND
Formaldehyde	0 1	ND
Freon 11	5 0	0 045
Freon 12	200	ND
Freon 113	150	0 57
Freon 114	200	ND
Hydrogen chloride	1 0	
Hydrogen fluoride	0 1	
Hydrogen sulfide	20	
2-methyl butanone	20	ND
Mercury	0 01 mg/m^3	
Monochloroacetylene	0 01	ND
Ozone	0 02	
Phosgene	0 05	ND
Sulfur dioxide	1 0	
Trans dichloroethylene	0 1	ND
1,1,1 trichloroethane	5 0	0 0003
Trichloroethylene	0 1	0 0003
Vinylidene chloride	0 1	0 042
Total chlorides	25 mg/m^3	
Halogenated hydrocarbons	–	
Unknowns - chlorinated	–	ND

ND – None detected

TABLE 10 – COMPOUNDS FOUND IN RECOVERY SAMPLE BOTTLE CONTAINER (TEST J3) – Concluded
[All results in ppm unless noted]

Nonrestricted compound	Result
Acetaldehyde	ND
Acetate, butyl	ND
Acetate, n-butyl	ND
Acetate, cellosolve	ND
Acetate, methyl	ND
Acetate, n propyl	ND
Acetonitrile	ND
Alcohol, isobutyl	0 016
Alcohol, sec butyl	0 002
Alcohol, tert-butyl	ND
Alcohol, capryl	ND
Alcohol, n pentyl	ND
Alcohol, 2 propyl	ND
Alcohol, n propyl	ND
Aromatic hydrocarbons C_9	0 004 mg/m^3
Aromatic hydrocarbons C_{10}	0 010 mg/m^3
Benzaldehyde	ND
Carbon tetrachloride	ND
Chlorobenzene	0 003
Chlorotrifluoroethylene	ND
Cyclohexane	ND
Cyclohexene	ND
Decalin	ND
Dichlorobenzene	0 001
1,1 dichloroethane	ND
1,2 dichloroethane	ND
Dimethyl cyclohexane	ND
Dimethyl disulfide	ND
Dimethyl sulfide	ND
Ethyl benzene	0 058
Ethylene glycol monoethyl ether	ND
Ethylene glycol monomethyl ether	ND
Freon 21	ND
Freon 22	See Freon 11
Furan	0 006
n heptane	ND
n hexane	0 006
Hydrocarbons, C_1 C_2 C_3 C_4-C_5	8 06 mg/m^3
Indene	ND
Isoprene	ND
Methane	
Methyl cyclohexane	0 004
Methyl cyclopentane	ND
Methyl isobutyl ketone	ND
Methyl propenyl ketone	ND
Mesitylene	0 002
n octyne	ND
Paraffins C_6	ND
Paraffins C_7	ND
Pinene	ND
Silicone	ND
Styrene	0 001
Tetrachloroethane	0 001
Tetrachloroethylene	0 013
Toluene	0 010
Trimethyl hexane	ND
m xylene	0 001
o xylene	0 0009
Unknowns, nonchlorinated	0 022 mg/m^3

ND – None detected